

METALLURGIA

The British Journal of Metals

(INCORPORATING THE METALLURGICAL ENGINEER)

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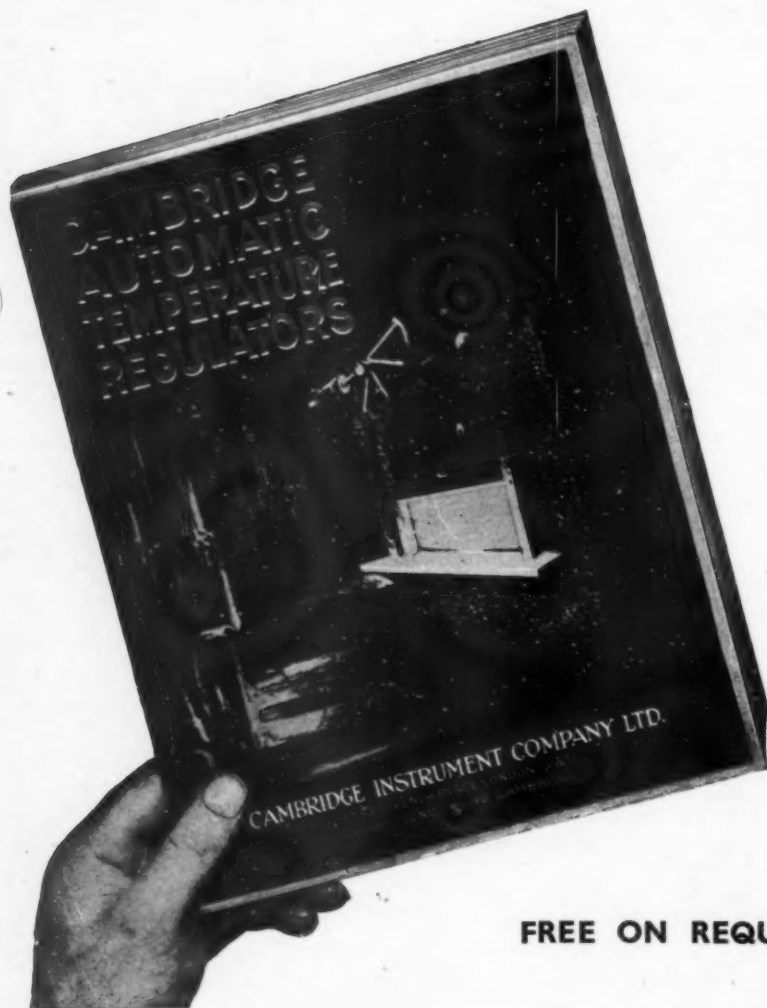
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Published monthly by THE KENNEDY PRESS, LIMITED.

REGISTERED OFFICE: 31, King Street West, Manchester, 3.
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METALLURGIA

THE BRITISH JOURNAL OF METALS.

INCORPORATING "THE METALLURGICAL ENGINEER"

SEPTEMBER, 1946

VOL. XXXIV No. 203

Creative Thinking

WE tend to give credit for the progress so far achieved to the discovery or development of power units, materials, machines, etc., but industry's greatest resource is undoubtedly the development of the human factor. Yet the productive power, initiative and intelligence latent in every person is largely untapped. Every human being is potentially a creative thinker, and if this faculty could be fostered and developed, it would not only greatly aid industrial progress but would accelerate human progress.

Few human abilities play a greater role in industrial progress than the skilled ingenuity and creative thinking which underlie both inventiveness and resourceful leadership, but it is not easy to determine what an individual can do to use his creative powers most effectively when faced with a concrete problem, and to develop in himself the art of creative thinking. These questions are considered in a very able manner by William H. Easton* who has made both his analyses of this problem and his advice so fundamental as to free them completely from routine and to make them applicable to everyone whose work involves creative originality in any field. Even the great majority of people whose creative originality remains latent will benefit from his views.

Ever since man first became man, people with a talent for original thought have played decisive parts in advancing human progress. But they were few and far between. The vast majority never originated anything. To-day, we are more progressive because we have many more innovators in every field of human endeavour. The general situation, however, is not greatly altered. Most people do only what others have done before them, and if they have original ideas they fail to develop them. All really new things of importance are still being produced by a relatively small number of exceptional individuals. These individuals Mr. Easton regards as "creative thinkers" and the mental processes that enable them to produce new things "creative thinking."

He suggests that creative thinkers are born, not made. Some people want to think creatively while others do not. Education can help to develop latent powers, but is not a vital factor. Many highly trained persons are sterile creatively, while others accomplish outstanding results in spite of an almost total lack of formal instruction. But what traits are essential for genuine achievement in creative thinking? Mr. Easton draws up a list that will be useful for self-analysis or for gauging the capabilities of others. Thus, the creative thinker must have ambition, for a clear and powerful urge to accomplish something notable is the mainspring of all creative endeavour. When he meets with the difficulties that inevitably arise in the course of his work, he must persist

in struggling with them until he has overcome them, no matter how long it may take. For this he requires both energy great enough to sustain him in the most arduous kind of mental labour and also complete confidence in his ability to attain final success. As the scope of his creative work depends upon his store of knowledge, he should be constantly engaged in enlarging this store by study, experiment, and observation. He must therefore have a high capacity for self-instruction. He must have enthusiasm, devotions, passions. Creative thinking is not a purely intellectual process; on the contrary, the thinker is dominated by his emotions from the start to the finish of his work. He must possess an inquiring mind, and above all, a creative imagination.

Most people have little interest in their mental processes. They merely take them for granted and use them as a child uses its muscles—without the slightest regard for the mechanisms involved. This attitude is well enough for the average individual; but if the creative thinker wishes to become an efficient workman he must know his tools and understand their uses. Hence it is necessary to take a look at the contents of his toolbox. There is only a single set of mental processes here, for all are indispensable; but for our purposes we shall divide them into two groups, which we shall call non-creative and creative, respectively. Chief among the *non-creative mental processes* are observation, reflection, remembering, reasoning, judgment.

These processes enable the thinker to collect data from his store of knowledge and from the results of his research; to evaluate each item in terms of his immediate purposes; to select those that are of use to him and to reject the rest; and to organise his selections in some systematic manner. They also enable him to come to certain conclusions as to the significance of his collected material; and finally, they provide him with means for determining the probable validity of these conclusions. Thus, the *non-creative mental processes* form the basis of logical thought and therefore of all sound creative thinking.

For the highly special tools used by the creative thinker, the ones with which he brings into existence that which did not exist before, we must look to the *creative mental processes*, three of which are used by every thinker. These are imagination, inspiration and illumination. In addition to these three processes there may be others. Thinkers of all lands and of all times have claimed that ideas have come to them through such media as intuitive insight, visions, and communications from the spirit world. Many of these manifestations can probably be referred to the listed processes which not infrequently operate so dramatically and unexpectedly as to favour a mystical explanation of the results; but in some cases, creative powers of a different order may be involved. If so, these powers act sporadically and unpredictably and have no place in creative thinking.

* Mech. Eng. 1946, 68, 697-704.

The creative thinker uses these creative processes deliberately, purposefully, and for definitely selected ends. He enjoys using them and will sacrifice much for opportunities to do so. He is not necessarily more intelligent than his fellows; he simply has a different temperament. The actual use of the creative processes is instinctive; no one needs to be told how to exercise his imagination or what to do when inspiration occurs. But the efficient use of these processes is a different matter.

Efficiency in creative thinking consists in carrying on creative work to a successful conclusion with a minimum expenditure of time, mental effort, and nervous energy. It is a subject that so far has been given little attention by thinkers, but there are probably few who cannot do better work by using their mental tools more efficiently. For this purpose one must know what process will be employed under given circumstances; what are the capabilities and limitations of each process; what conditions favour and what conditions inhibit the activity of each process; and how each process can be controlled, in so far as this is possible.

In non-creative deliberate thinking, such as reasoning, performing mathematical operations, and preparing factual reports, the imagination is prohibited from taking a leading part, for it cannot be permitted to alter any of the data being dealt with. But in all phases of creative deliberate thinking, the imaginations is continuously active; the thinker employs it at every stage of his work. He cannot, however, always use his imagination when he needs it. Sometimes it is ready to do what the thinker wants it to do, and sometimes it isn't. This independence of the imagination gives every thinker many bad hours. Nothing is more exasperating than to settle down with every intention of working and then find that one's imagination has pressing business elsewhere.

Creative thinking, therefore, cannot be undertaken in cold blood. The imagination concerns itself only with whatever has the strongest emotional appeal for the thinker at the moment and refuses to deal with anything else. This does not mean that the thinker should drop work whenever he is not in the proper mood, for that wastes time. Nor does it mean that he should try to force an unwilling mind to function, for that wastes energy. What it does mean is that, if he wants to get on with his work, he must gain something that he lacks temporarily; namely an overwhelming interest in the job before him.

When engaged in creative thinking, the mind is under a strain. Eventually, the imagination tires, and it takes an effort to think up something new. At this point it is time to stop. If anything further is attempted it will be done poorly. Noncreative thinking, which does not call upon the imagination, is another matter, and one can turn to it with relief when wearied with creation. Thinkers should bear this in mind and so arrange their work that they can fall back on noncreative operations whenever their creative power begins to flag.

During the course of his work a creative thinker may pass through a variety of mental states, such as indifference to a project in the beginning; a rather sudden acquirement of interest in it; complete absorption as he proceeds to work on it; annoyance when stopped by a problem; weariness, if he works too long on it; exasperation if it finally defeats him; delight when illumination shows him the solution; and intense creative activity as he develops his new ideas.

Those engaged on creative work will appreciate that Mr. Easton had in mind workers on inventions, development, research, or writing, and will recognise his descriptions of moods, methods, and mental processes and will probably agree that the creative processes of imagination, inspiration and illumination attend his success in the order named, regardless of whether the field be science, invention, or the arts. In industry, however, creative thinking has very limited scope for the vast majority in it. Fifty or a hundred years ago creative thinking was applied to a relatively greater extent than in these modern times, especially among what can be regarded as the craftsmen in industry. To-day, apart from few exceptions, only a few are required to think creatively and the remainder must carry out instructions; whatever latent faculty for creative thinking they possess is subdued and their lives are in a measure frustrated.

There is work here for an outstanding creative thinker to create or restore enthusiasm in others for the specialised work upon which they are engaged; to develop this latent faculty, and thus counteract, in some appreciable degree, the effects of this machine age. The development and successful application of an idea of this nature would indeed promote industrial progress and, more important, human happiness.

Literary Research Survey Service

THERE are few who do not appreciate the need for careful literary research when an investigation is contemplated. As we have said in an earlier issue of this journal, discovery and invention do not spring full-grown from the brains of man, they are the products of long and arduous research, and their development is the result of much experimental investigation during which they are developed and improved. Actually the labour of a host of men, great laboratories, and long, patient, scientific experiment are involved in building up the structure of knowledge, not stone by stone, but particle by particle. This adding of fact to fact, some day brings forth a revolutionary discovery, an illuminating hypothesis, a great invention.

Unfortunately information regarding the facts built up in any particular field of enquiry are not easy of access, even when the source of information is known, and a very careful survey of the literature on the subject on which investigation is contemplated is a necessary preliminary, otherwise much time and material may be wasted in covering ground which has already been carefully investigated. In order to assist readers we have made arrangements with a London research consultant to undertake the compilation of bibliographical and literary research surveys within our field.

Frequently we are approached by readers requiring literature surveys on various specialised subjects, but our facilities for giving the maximum assistance have been and still are somewhat restricted. It is believed however, that the new arrangements will provide a more reliable service. Although obviously dependent upon the nature of the investigation required, the fees for this service will be low. Initial inquiries should be made through METALLURGIA offices, addressed to the Editor.

MR. W. S. SPICER, chief buyer and stores superintendent of Hadfields, Ltd., has been appointed a local director of that company.

Ductility of Metals and Alloys used in Construction

The Effects of Notching under Axial and Eccentric Loads*

By Dr. Georges Welter

Ecole Polytechnique, Montreal

This paper records and discusses results of tests made on construction materials in order to establish a classification, with respect to their ductility, of light metals and alloys in comparison with other heavy structural materials. The effect of notching under axial and eccentric loads has also been investigated. For this purpose, standard and special notched specimens were tested under axial and eccentric loads producing single tension as well as combined tension and bending stresses.

Eccentricities up to $\frac{1}{2}$ in. seem to have no harmful influence on standard specimens of mild steels while light alloys and brass are not ductile enough to stand these critical conditions. In specially brittle material such as cast iron there appeared to be a closer relationship between the ultimate strength and the degree of eccentric loading.

Similar results were obtained with conical specimens which provided a better differentiation amongst materials of different degrees of ductility.

Stress-strain curves of commercial metals and alloys in the "as received" as well as in the "cold stretched" and the "annealed" conditions, and tested under various eccentricities, give interesting information regarding the ductility of these materials. The energy absorbed during the loading process also permits a certain evaluation of the materials with regard to their strength and ductility. These diagrams show that for eccentrically loaded notched specimens, very ductile materials lose little of their properties as compared with axial loading, while less ductile and brittle materials lose rapidly their ultimate resistance and stand very small amounts of energy; these characteristics provide a useful index for the evaluation of strength and ductility. Nickel-copper and nickel-iron alloys are, in this respect, outstanding and far superior to light alloys.

A certain classification is given based on various indices for ductility and strength properties of notched, axially and eccentrically loaded specimens.

Introduction

THE mechanical properties, and in particular the ductility, of metals and alloys used in modern construction, have not as yet been sufficiently investigated to permit predicting their behaviour in service. Our knowledge of the ductility of metallic material is derived from the results of tensile tests by determining the percentage of elongation and reduction of area of the test specimen, or in a qualitative manner, from the results of cold bending and cupping tests. It is evident that a material with favourable strength properties, showing simultaneously a high degree of ductility, is desirable for most engineering purposes. However, the minimum desirable value for the ductility of structural materials as a function of elongation or reduction of area is not

known. What we know is that high ductility prevents stress concentration and consequently local and eventually total cracking of the material; high ductility levels off internal stresses which are made harmless, and it reduces notch sensitivity under static and dynamic loading of the material. We also know that fatigue durability and shock resistance are increased by materials with high ductility characteristics. Ductility serves to overcome over-stresses, eccentric loading, external and internal defects or anisotropy of any kind, of the material. In terms of service conditions this means that ductility is necessary to deal with the different shapes of structural elements as abrupt changes in sections, notches, fillets, key ways, grooves, holes and surface finish, representing spots of predilection for dangerous incalculable combined stresses. A very high ductility of the material is necessary to prevent local failure in these spots. Non-symmetrical loading, insufficient alignment of the elements, are in general the external sources of uncontrollable, localised working

stresses. Without any doubt, ductility is the most effective insurance against high stress concentration factors. Many scientific investigations have been carried on this subject and a detailed discussion of this important problem will be found in the bibliography compiled by Gillett.¹

The purpose of the investigation, whose results are described in the following pages, was to establish a classification based on the ductility as well as the strength properties of light metal and alloys compared to other structural materials used for engineering purposes. In order to investigate the various factors having a marked influence on the plastic deformation of metals, tensile tests under axial and eccentric loads were carried out on cylindrical and flat specimens. In addition to the yield point, indicated on the stress-strain curves, the ultimate load, the ductility values such as the elongation and the reduction of area, and the total absorbed energy were determined

* This investigation work, started in 1942, was made possible through funds from the National Research Council, Ottawa (Committee on Assisted Research). The author wishes to record here his thanks to the Council for its financial aid. He also wishes to express his appreciation to Mr. J. Trudel, a student at Ecole Polytechnique de Montreal, who helped in the preliminary investigation work which he subsequently described in his graduation thesis in May, 1943, using eccentrically loaded notched specimens.

¹ E. W. Gillett, *A.S.T.M.*, vol. 40, p. 651, 1940, with 60 references; and *Machine Design*, December, 1943, p. 121.

by measuring the area under the load deformation diagram recorded by the machine during the tensile test. This area, however, does not provide any information on the behaviour of the material with particular reference to the "notching" effect. For this purpose, a special series of tests was made on eccentrically loaded notched specimens.

The materials were tested in the "as received" condition and after deformation by "cold stretching" in order to reduce the high degree of ductility of most structural materials. Series of information tests with "annealed" material were also carried out.

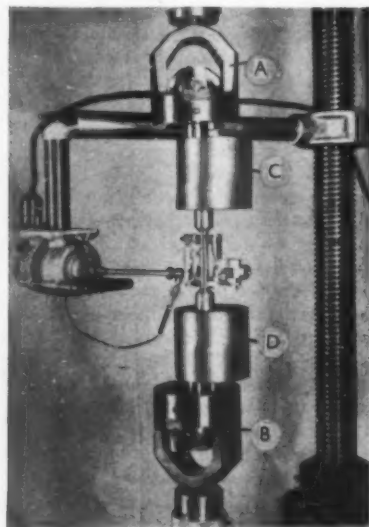


Fig. 1.—Device for axial and eccentric loading of the specimens.

Description of Apparatus and Testing Technique. (a) Tension Tests

The main tests were made on a 60,000 lbs. Baldwin Southwark testing machine with cylindrical, notched and flat specimens. It is a well-known fact that, with the usual loading devices using threaded specimens or specimens with cylindrical heads, a complete axial or concentric loading, insuring uniform distribution of the load over the whole cross section and along the whole gauge length of the specimen, is not possible.²

In order to insure perfect loading of the specimen axially, universal joints *a* and *b* Fig. 1 were used for axial tests. By means of this device, the load is transmitted from the grips of the

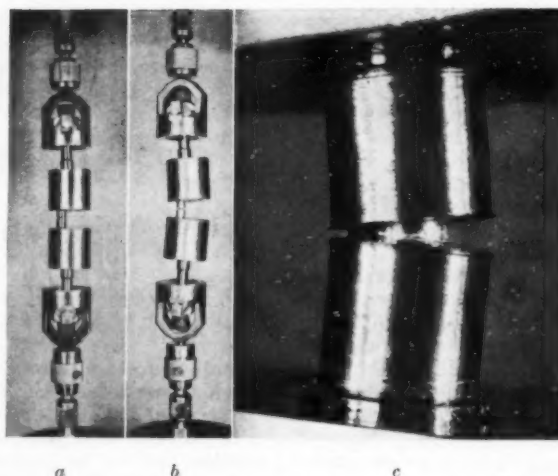


Fig. 2.—Notched specimens with $\frac{1}{4}$ in. eccentricity before tests and at ultimate load.

machine to the specimen by two pairs of crossed knives, the point of intersection of the axes of these knives corresponding to the axis of the specimen. Furthermore, these universal joints present the additional advantage of permitting the application of a load with a given eccentricity. By means of cylindrical blocks *c* and *d* Fig. 1 provided with eccentric threaded holes on both sides, the specimens are fastened between the universal joints with the exact amount of eccentricity desired. In order to obtain the eccentricities required, holes were provided in each block at $\frac{1}{4}$ in.,

the yield point, the ultimate load as well as the energy absorbed during the test, were determined by

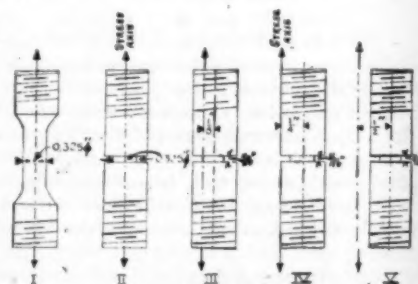


Fig. 3.—Cylindrical and notched specimens with eccentricities up to $\frac{1}{4}$ in.

TABLE I.—MATERIALS TESTED.

No.	Material	Condition	Nominal Composition, %	Hardness Brinell 10 mm. ball as received
1	Aluminum	Cast	90% Al + Cu, Zn, Fe, Si	58
2	Aluminum wrought	As drawn	Min. 99% Al	35
3	Brass	As drawn	62 ± 6% Cu, + 35% Zn + Pb	150
4	Copper	As drawn	99.9% Cu	75
5	Cast Iron Grey	Cast	3.50 C, 2% Si, 0.6 Mn, 0.5 P, 0.1 S	180
6	Cast Iron NI	Cast	As No. 5 + 1 ± 2% Ni	174
7	Duralumin	Heat-treated	4% Cu, 0.5% Mn, 0.5% Mg, Bal. Al	105
8	Iron Armco	Wrought	> 99.9% Fe	132
9	Magnesium Alloy I (X)578	Wrought	6 ± 7% Al, 1% Zn, < 0.3 Si, 0.2% Mn	63
10	Magnesium Alloy II (XA)598	Wrought	9.5 ± 10.5% Al, 0.3% Zn, < 0.3% Si, 0.1% Mn	80
11	Monel RA	Wrought	67% Ni, 30% Cu, 1.4% Fe, 1% Mn	209
12	Monel K SA	As drawn	0.73% Mn, 0.31% Si, 0.58% Ti	262
13	Monel K SB	As drawn and heat-treated	64.2% Ni, 29.7% Cu, 1.44% Fe, 0.73% Mn, 0.31% Si, 0.58% Ti	292
14	Monel K SC	Annealed	2.78% Al, 0.14% C, 0.02% Cr	183
15	Monel K SD	Annealed and heat-treated		275
16	Nickel	Wrought	99.4% Ni, 0.2% Mn, 0.15% Fe, 0.1% Cu	94
17	Steel, mild, I	Wrought	0.1 ± 0.2% C, 0.3 ± 0.6% Mn	147
18	Steel, mild, II	Wrought	0.15 ± 0.25% C, 0.3 ± 0.6% Mn	152
19	Steel, med., B	Wrought	0.35 ± 0.45% C, 0.6 ± 0.9% Mn	170
20	Steel, med., BB	Wrought	0.4 ± 0.45% C, 1.10% Mn	256
21	Steel, med., BA	Wrought	0.4 ± 0.5% C, 0.6 ± 0.9% Mn	219
22	Steel, hard, C	Wrought	0.85 ± 1.0% C	219
23	Steel, stainless, GA	Wrought	18% Cr, 8% Ni	230
24	Steel, Ni-Cr, EA	Wrought	0.4% C, 0.75% Mn, 1.25% Ni, 0.6% Cr, 0.15% Mn	198
25	Steel, Cr-Va, G	Wrought	0.5% C, 1.0% Cr, 0.25% Va	148
26	Zinc	Wrought	> 99.82% Zn	50

² Georges Welter, "The Yielding Phenomenon of Metals, METALLURGIA, Vol. 31, No. 184, February, 1943, pp. 207-210.

means of these curves.

Test Specimens

The axial and eccentric tensile tests were made on cylindrical specimens of 0.325 in. diameter at the base and 0.075 in. width of the notch; the eccentricities of the cylindrical part of the specimen were of $\frac{1}{8}$ in., $\frac{1}{4}$ in. and $\frac{1}{2}$ in. for all tests (see Fig. 3). About 550 specimens were used in the course of this work; some of the tested specimens are shown in Fig. 4.

Material Used

The various commercial metals used are listed in Table I, which gives their typical composition. They were received in bars of $\frac{3}{4}$ in. diameter and in plates of $\frac{1}{2}$ in. \times $1\frac{1}{2}$ in.; most of the material was tested in tension for two different conditions; in the "as received" condition, in order to obtain the characteristics under the usual service conditions of the material; and in the "cold stretched" condition, that is after the material had been cold worked by stretching up to the ultimate strength of the bar, indicated by a necking of the specimen. Some of the metals were also tested in the "annealed" condition.

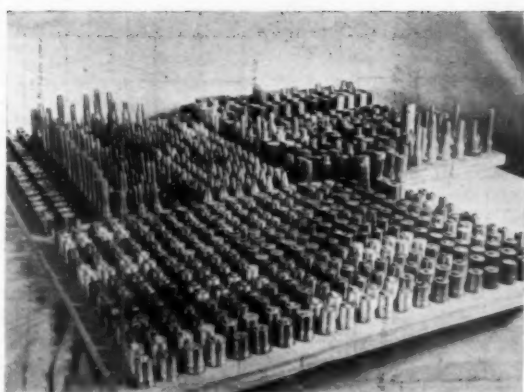


Fig. 4.—Parts of the specimens after the tests.

Experimental Results A—Preliminary Tension Tests

Before undertaking the main investigation, a series of preliminary tests was necessary to find the best suitable shape of the specimen in order to obtain results which would show, in a most characteristic way, those properties of the material which are chiefly connected with their ductility.

(a) *Standard specimens.*—A first step was made in this direction using specimens of standard dimensions ($\frac{3}{8}$ in. diameter, $1\frac{1}{2}$ in. length) similar to No. 6 in Fig. 5, adjusted in the eccentric blocks and fixed between the universal joints. Table II shows that for ductile materials No. 1 to 4, that is mild steel, medium steel and brass, the results of tests carried out with eccentricities of $\frac{1}{8}$ in. and $\frac{1}{4}$ in.

vary very slightly from the results of tests where the load was applied axially. Even when tested with an eccentricity of $\frac{1}{2}$ in., the first two materials showed no weakness whatever. It is rather surprising that, under such severe testing conditions, there was no appreciable change in such factors as ultimate load, elongation, reduction of area, or even energy absorbed during the test. The ratio of the results for the two types of tests, in the cases of strength and energy absorbed, is fairly close to unity. All that could be observed during these

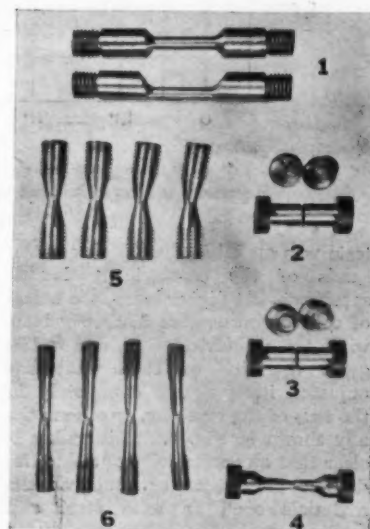


Fig. 5.—Specimens of different shapes.

TABLE II.—STANDARD SPECIMENS

No.	Material	Axial load				Eccentricity $\frac{1}{8}$ in.						
		Ultimate strength lb./sq. in.	Elongation %	Reduction of area %	Energy total in. lb.	Ultimate strength lb./sq. in.	Elongation % of fibre in		Reduction of area %	Energy total in. lb.	Strength ratio ecc.	Energy ratio ecc.
							Compr.	Tension			axial	axial
1	Steel, I	68,800	37.7	63.2	26,000	68,200	32.2	34.3	61.5	24,500	0.99	0.94
2	Steel, med. B. . . .	117,200	19.4	44.2	25,350	118,100	22.7	22.9	44.8	29,000	1.01	1.15
3	Steel, med. BA . . .	89,500	31.5	56.0	28,200	89,200	29.4	32.7	55.0	26,200	0.99	0.93
4	Brass	59,600	22.5	48.0	14,200	59,600	23.9	25.2	48.4	14,750	1.00	1.04
5	Duralumin	64,100	26.4	46.0	18,900	64,000	25.0	26.6	30.7	16,000	1.00	1.01
6	Magnesium Alloy, I	46,000	18.7	11.6	6,312	46,900	13.0	13.8	49.0	7,920	1.02	1.35
7	Cast Iron	22,000	—	—	433	19,375	—	—	—	340	0.88	0.76
8	Cast Iron, Nickel . .	22,400	—	—	460	18,500	—	—	—	300	0.82	0.65

No.	Ultimate strength lb./sq. in.	Eccentricity $\frac{1}{4}$ in.		Reduction of area %	Energy total in. lb.	Strength ratio ecc.	Energy ratio ecc.	Eccentricity $\frac{1}{2}$ in.		Reduction of area %	Energy total in. lb.	Strength ratio ecc.	Energy ratio ecc.
		Elongation % of fibre in						Elongation % of fibre in					
		Compr.	Tension					Compr.	Tension					axial	axial
1	68,200	32.4	34.4	63.8	23,600	0.99	0.91	68,500	32.9	35.2	63.2	0.99	0.91
2	118,100	21.2	21.3	44.0	30,600	1.01	1.21	119,000	19.2	19.5	45.1	1.01	1.17
3	89,000	27.0	29.1	56.2	26,800	0.99	0.95	89,300	27.8	29.4	55.8	0.99	0.98
4	59,800	23.4	25.8	47.5	14,500	1.00	1.02	53,400	4.0	—	4,600	0.89	0.33
5	63,200*	13.0	13.8	10.5	10,200	0.98	0.84	57,000*	7.3	9.7	7.8	0.89	0.33
6	46,000	11.4	11.4	10.5	6,700	1.01	1.06	25,900*	4.6	5.8	16.0	0.86	—
7	12,900	—	—	—	300	0.61	0.46	6,100	—	—	110	0.38	0.25
8	11,250	—	—	—	180	0.50	0.23	4,300	—	—	60	0.19	0.13

* Broken in fillets

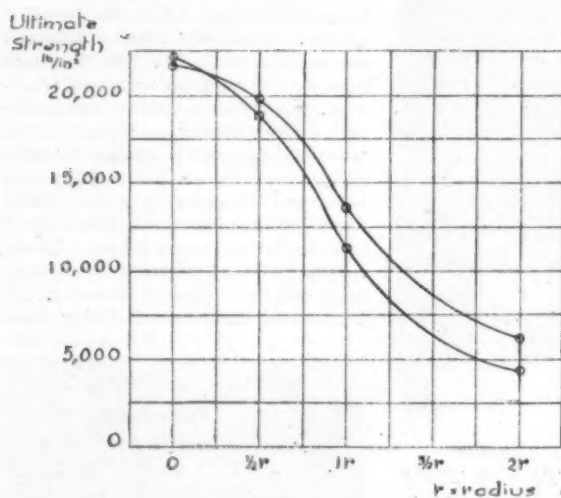


Fig. 7.—Results of cast iron specimens under axial and eccentric load.

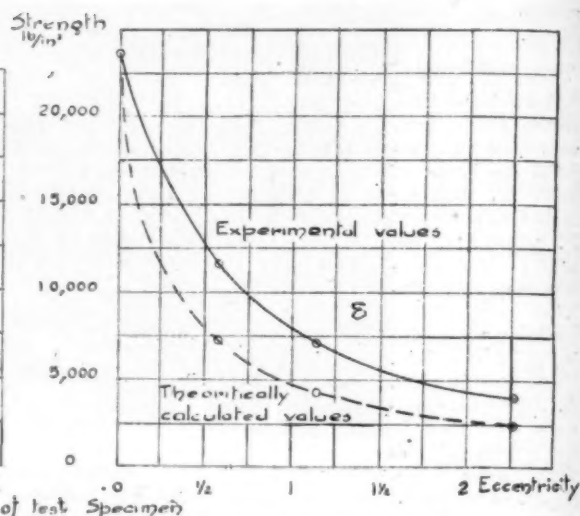


Fig. 8.—Experimental values in comparison of theoretically calculated values of conical cast iron specimens.

tests was an initial bending near the heads of the eccentrically loaded specimens. At higher loads, the heads of the specimens were distinctly bent while the cylindrical part, due to the great ductility of these materials adjusted itself nearly completely in the axis of the machine, as schematically shown in Fig. 6. This makes it clear that an eccentricity of even $\frac{1}{2}$ in. does not affect those extremely ductile materials such as mild steel and medium steel. Brass, however, tested under such eccentricity already shows a smaller ultimate strength, a very low elongation as well as unfavourable strength and energy ratios. Further-

more, the ductility of the next two materials, Nos. 5 and 6 (duralumin and magnesium alloy I) is already influ-

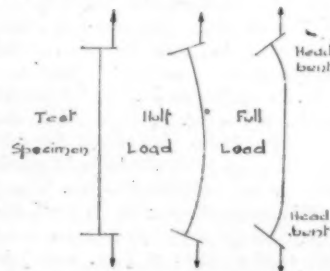


Fig. 6.—Scheme of test specimen under an eccentric load.

enced harmfully by loading with $\frac{1}{4}$ in. and $\frac{1}{2}$ in. eccentricities. Duralumin specimen No. 5 supported an eccentricity of $\frac{1}{2}$ in. without being particularly affected, but broke in the threaded head with $\frac{1}{4}$ in. eccentricity, showing smaller elongation (13–13.8% instead of 28% of axial load), reduction of area (10.5 instead of 46%) and total energy in comparison to the axially loaded specimen (10,200 in.-lb. instead of 18,900 in.-lb.). At $\frac{1}{2}$ in. eccentricity, the breaking load, beside the other properties, was also already distinctly smaller (57,000 lbs. per sq. in. instead of 64,000 lbs. per sq. in.) The cylindrical part of the duralumin specimen

TABLE III.—CONICAL SPECIMENS.

No.	Material	Axial Load					Eccentricity $\frac{1}{4}$ in.						
		Ultimate strength lb./sq. in.	Elongation %	Reduction of area %	Energy total in. lb.	Ultimate strength lb./sq. in.	Elongation % of fibre in		Reduction of area %	Energy total in. lb.	Strength ratio ecc.		Energy ratio ecc.
							Compr.	Tension			axial	axial	
1	Mild Steel, I ..	73,000	22.0	56.4	26,400	72,600	22.0	25.0	57.7	27,800	0.99	1.06	
2	Steel, Med. B. ..	96,500	16.0	58.5	18,680	90,600	20.0	20.3	60.2	21,400	0.93	1.15	
3	Steel, G. ..	84,800	11.1	62.0	6,060	84,500	11.2	11.3	58.0	3,550	0.99	0.92	
4	Brass ..	71,300	14.3	33.6	15,500	73,500	7.0	10.0	31.8	14,800	1.05	0.95	
5	Duralumin ..	73,400	11.0	32.6	18,600	71,700	14.0	15.0	35.6	19,600	0.99	1.06	
6	Magnesium Alloy, I	50,000	9.8	21.5	7,000	49,500	8.0	10.9	14.6	6,580	0.99	0.94	
7	Cast Iron ..	20,000	—	—	770	11,100	—	—	—	336	0.55	0.43	
8	Cast Iron, Nickel ..	23,600	—	—	910	11,600	—	—	—	368	0.49	0.40	

No.	Eccentricity $\frac{1}{2}$ in.						Eccentricity $\frac{1}{4}$ in.					
	Ultimate strength lb./sq. in.	Elongation % of fibre in		Reduction of area %	Energy total in. lb.	Strength ratio ecc.	Ultimate strength lb./sq. in.	Elongation % of fibre in		Reduction of area %	Energy total in. lb.	Strength ratio ecc.
		Compr.	Tension					Compr.	Tension			
1	72,300	22.0	26.0	58.0	29,700	0.99	71,300	19.0	29.0	58.1	29,400	0.97
2	90,300	19.7	31.5	61.5	20,800	0.93	89,700	23.2	25.0	62.2	21,900	0.92
3	84,800	11.0	11.3	62.0	6,050	1.00	83,600	11.3	12.1	64.0	6,470	0.98
4	71,300	8.9	13.5	33.6	15,800	1.00	71,200	6.0	16.0	34.4	16,800	0.99
5	70,700	12.0	16.0	35.1	19,800	0.97	71,000	8.9	14.0	30.0	20,300	0.98
6	49,000	6.0	6.0	9.6	6,970	0.98	38,500	3.0	11.0	16.3	4,000	0.77
7	8,140	—	—	—	228	0.40	4,070	—	—	—	78	0.20
8	7,000	—	—	—	168	0.29	4,000	—	—	—	114	0.16

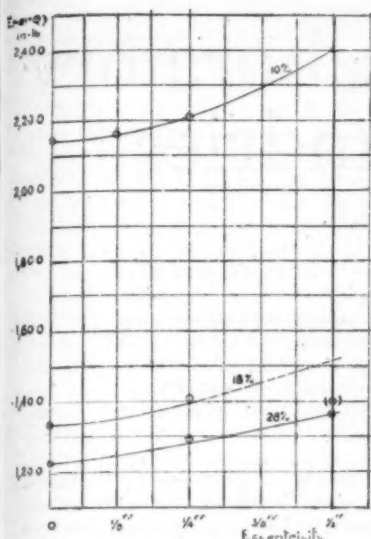


Fig. 9.—Energy absorbed by previously 10 to 28% cold worked conical steel specimens.

stood the eccentricity up to $\frac{1}{4}$ in. Unlike steel, this material is not ductile enough to support strong local deformations, so that the fracture occurred at the bottom of the threaded head.

Magnesium alloy No. 6 did not resist $\frac{1}{4}$ in. eccentricity and broke in the threaded head of the specimen at small loads of 25,000 lbs. per sq. in., compared to 46,000 lbs. per sq. in. for the axial loading.

The most interesting result of this preliminary series of tests with standard cylindrical specimens was the behaviour of brittle materials such as cast iron (tests Nos. 7 and 8). Under these severe testing conditions, these materials showed a clear relation between the ultimate load and the degree of eccentric loading. Already at $\frac{1}{4}$ in. eccentricity the load falls down by 10 to 15%, and the absorbed energy is 20% to 30% lower; at $\frac{1}{2}$ in. eccentricity, this tendency is much more pronounced and, at $\frac{1}{2}$ in. eccentricity, the ultimate strength is only $\frac{1}{2}$ to $\frac{3}{4}$ of that under the original axial load, and the energy ratio is even lower. These results, plotted in Fig. 7, where the eccentricity is expressed in function of the radius of the specimen, give a characteristic record for a material with a very low degree of ductility such as cast iron.

(b) *Conical Specimens.*—The results of tests on cylindrical specimens providing little information on the ductility of materials, a similar series of tests was carried out with conical

specimens of a more rigid shape than the standard cylindrical specimens. In the reduced section, the diameter of these specimens was $\frac{7}{16}$ in., the threaded ends $\frac{1}{2}$ in. diameter and the length between the heads was $1\frac{1}{2}$ in. Some of these specimens, after the axial and the eccentric tests, are shown in Fig. 5, No. 5. In all these tests, the fracture took place in the middle of the specimen. Complete redistribution of the load in the cylindrical gauge length during eccentric testing, was possible in the preceding tests, but could not be achieved with specimens of this shape.

From the results shown in Table III it can be seen that for the three different steels Nos. 1, 2 and 3, as well as for brass and duralumin (tests Nos. 4 and 5), an eccentricity of even $\frac{1}{4}$ in. has not yet a very detrimental influence on the resistance of these ductile materials. In spite of the irregular elongation showing differences up to 10% in opposite fibres of the specimens, there is however no appreciable difference in the ultimate strength. Moreover, it seems that the energy absorbed at a certain degree of eccentricity is even somewhat higher for the five materials tested than for the specimens axially loaded.

Unlike these ductile materials, magnesium alloy I, test No. 6, and especially the brittle cast irons Nos. 7 and 8 are very sensitive to eccentric loading. At $\frac{1}{4}$ in. eccentricity, the magnesium alloy shows an ultimate load lower by about 23% and a total energy lower by about 42% as compared with axially loaded specimens.

As in the preceding series of tests, the two cast iron alloys (tests Nos. 7 and 8) again showed poor resistance to eccentric loading. The results of test No. 8 (cast iron) are plotted in Fig. 8 where the ultimate load is expressed in function of the radius of eccentricity. The resulting curve is remarkably regular and in fair accordance with the curve drawn from theoretical values derived with the assumption that the material breaks at the end of the elastic range of the material.

Considering that the eccentric loading tests on conical short specimens of ductile material, such as steel and other alloys, had left their mechanical properties practically undisturbed, another preliminary series of tests was made on mild steel cold-worked to 10%, 18% and 28% elongation. The specimens for these tests were taken from three short bars of mild steel (Table I, No. 17) which had been

cold-stretched up to the "necking" point. These results show that even after plastic deformation of the material by cold-stretching, and using rigid and conical test specimens, the breaking strength under eccentric loading is only slightly smaller than under axial loading. It is rather surprising to find that under such severe conditions (28% cold-stretching), the ultimate load for the conical shaped mild steel specimen tested with $\frac{1}{4}$ in. eccentricity, decreased only by a small percentage (6 to 7%). The total energy, necessary to break the specimen, was, in all cases of eccentric loading, distinctly higher (about 6 to 12%) than under axial loading, as shown in Fig. 9.

B.—Main Tension Tests

The results of the above-described tests indicated that useful information might be expected on the ductility of plastic materials when notched specimens are used. It is a well-known fact that the geometrical shape of the test specimen greatly influences the distribution of stresses in the effective volume of the gauge length during the breaking process of the specimen. By providing a sharp notch in a cylindrical specimen, the highest possible local plastic deformation in a material can be secured during axial and eccentric loading. By this means the metal, submitted to a three-dimensional system of stresses at the root of the notch, cannot flow and behaves in a brittle fashion. Therefore, it can be expected that materials, which would appear ductile in a cylindrical shape even though they may show an unfavourable cohesive shear-strength ratio, will, under this kind of test, reveal their real qualities of toughness and ductility. Accordingly, the main series of tension tests were made on standard cylindrical and on notched specimens as shown in Figs. 3 and 5. The notch was 0.08 in. wide and the diameter at the bottom of the notch was, for most specimens, 0.325 in. The specimens with threaded heads were fixed in the cylindrical steel blocks and loaded between the universal joints with successive eccentricities of $\frac{1}{4}$ in., $\frac{1}{2}$ in. and $\frac{1}{2}$ in. (Figs. 2a, b, x).

(To be continued).

STEELS IN ENEMY AIRCRAFT.

SOME copies of the above book are still available. Order direct from the Kennedy Press, Ltd. 31 King Street West, Manchester, 3, enclosing 10/6.

The Function of the Laboratory in Aluminium Foundries

By E. Carrington, M.Sc., M.I.Brit.F.

Foundry laboratories are becoming increasingly recognised as essential to the successful production of sound castings and in this article the author indicates that their function is to check the composition and physical properties of the metal, exercise technical control over manufacturing processes, and to institute a system of inspection on castings produced. But it is emphasised that there should be mutual respect between the metallurgist and the foundrymen to facilitate collaboration and the promotion of confidence in the contribution of each to the production of better and cheaper castings. Although the author is concerned with the production of aluminium castings, some of his views are applicable to all foundries.

DURING the war, aluminium alloy foundries were called upon to produce castings of very high quality. Men's lives depended upon their soundness, and therefore no risks must be taken. In order to ensure that the castings were good, and above all, consistent, it was necessary to organise an efficient system of scientific control. This included a laboratory, which checked the composition and physical properties of the metal used and exercised technical control over the manufacturing processes, and an inspection department which examined all castings, and scrapped any which were not quite sound. As these two departments were very closely associated, the chief metallurgist or chemist was generally made chief inspector also.

In order to be as sure as possible that the castings were sound without damaging them, X-ray examination was introduced, and this of course, became part of the laboratory's duties. The whole scheme of inspection was supervised by a visiting or resident A.I.D. (Aeronautical Inspection Department) Inspector.

Castings for aircraft will continue to be inspected in this way in peace-time, but it is worth while for the foundry to apply this scientific control to all castings made. The standard of inspection could be varied to suit each job. The main advantage of such a system is that the tendency of any castings to deteriorate in quality may be checked while it is still a tendency and before it becomes an actual fault. Inspection also enables defective castings to be removed from the production routine as soon as possible, and so saves the cost of further useless handling, fettling, heat-treatment, etc. It starts with the raw material and ends with the finished castings. It is by no means confined to the metal however. Sand is inspected on arrival, to see if it is of the correct kind, and also during its use, to ensure that specified conditions are being adhered to. Cores should also be inspected, those which are not dimensionally correct being rejected and any which should have been coated, but which have been sent out without a coating, being returned to the core shop to be coated. The checking of casting temperatures and the accuracy of pyrometers is also part of the inspection scheme.

Inspection of Castings

The details covered by the inspection department as far as the castings themselves are concerned are as follows :—

1. Analysis.—This must be as specified by the customer.
2. Physical properties.—Tensile strength, elongation, and any other property which may be asked for, such as a specific Brinell hardness.
3. General appearance.—Good surface, neat fettling. No rounded corners due to slight misruns. No cracks or sinks.
4. Size.—Must agree with the drawing, within the limits specified on the drawing.
5. Must be satisfactory under X-ray.
6. Must satisfy any special test asked for, such as pressure-tightness, non-porosity after machining, small grain size, etc.

This may seem rather an ambitious programme and in some foundries it may be considered to be unnecessary, but it must be emphasised that whenever a casting has to be used in aircraft it must be inspected in order to make sure that it is up to the standard required. The organisation set up to inspect these castings could easily be used to inspect all the castings made, so as to act as a guide to the production departments.

A.I.D. Inspector

Any foundry which makes aircraft castings must have an inspector who is approved by A.I.D. A.I.D. memo No. 1, issue 2, says, "The Chief Inspector should be immediately responsible to a director or some other senior official of the firm, and should not be under the control of those directly responsible for production. In other words the Chief Inspector shall be in such a position that his decisions are not liable to be overruled in the interests of output."

As the chief metallurgist or chief chemist will be responsible for the chemical composition, the physical properties, and the X-ray examination, and as he is not directly concerned with production, he would appear to be the most suitable person to be made chief inspector. In most foundries this arrangement is working quite satisfactorily. The chief inspector will form the link between the foundry and the supervising inspector who will either have an office in the foundry, if the amount of work calls for it, or will supervise several foundries and visit each one periodically.

As the laboratory forms this link between foundry and A.I.D., it will be worth while to consider its relationship with the foundry itself. Not long ago, the laboratory was looked upon as rather a nuisance and the metallurgist

was regarded by moulders—and even by heads of departments—as the man who “spoiled the metal” because of his practical inexperience. Probably this was due to faults on both sides. Admittedly, new laboratory men tend to stay in the laboratory and write quite good scientific papers, which, though of interest to the learned societies and the management, mean nothing to the moulders or foremen. It is important that laboratory and foundry should try to understand each other better, and as the workmen cannot spend much time in the laboratory, the metallurgist must put on an old suit and spend a great deal of time in the foundry. Many sections of the foundry work should definitely be under laboratory control and the metallurgist will find his time fully occupied if he does not go into the laboratory at all.

In view of this close contact with the workmen, the personal attitude of the metallurgist to them will greatly effect the success he makes of his job. Unfortunately, various processes are said to be “under laboratory supervision.” This suggests that the laboratory will be in charge, more or less at a distance, but that if anything goes wrong, the works department and not the laboratory, will be to blame. In his capacity as head of the technical department, and probably as chief inspector, the metallurgist has work to do which does not directly concern the foundry, but apart from this he should be at the beck and call of the foundry. He should show that he is not in charge of a watertight compartment which is closed to foundrymen, but of a service which is available for all who require it. If a moulder or an apprentice has a question to ask about the metal, or in fact, on any matter arising from the work, every effort should be made to answer it to his satisfaction. Queries about the most suitable text books are often asked and it is by going to some trouble to answer them that the metallurgist is able to be of real service and to gain the confidence of the workers. If foundrymen can come to the laboratory to see a test bar pulled or a section of a casting macro-etched to show the grain size, they will become far more interested in the work. If they can be shown the difference in grain size and physical properties caused by differences in casting temperature they will be much more convinced than by any theoretical explanation, and will see that the correct temperatures are used for their own jobs. Again, a demonstration of how sand tests are carried out, or a glance at a good and a bad casting on the X-ray fluorescent screen will show the foundryman that the metallurgist is not there merely to theorise, but to help the foundry in a practical way to turn out the best possible castings in the easiest way. He will see that this is best attained by pooling all knowledge and experience, and will begin to put forward his own problems. Occasionally these may seem illogical, or even silly to the metallurgist, but he must not forget that the foundryman has lived with them for a long time and takes them seriously. The metallurgist should therefore investigate them fully and he will generally find that there really is a problem and that he can help to solve it.

Great care should be taken to see that these problems are put forward through the foreman or with his knowledge and permission, as mistrust can easily be caused by people from one department talking to the men at work in another department without obtaining permission from the foreman.

Duties of the Metallurgist

Perhaps the duties of the metallurgist could best be considered in chronological order.

1. *Quotation.*—While many enquiries are quite straightforward, some may include metallurgical details about which the metallurgist should be consulted. If the alloy is an unusual one he should be asked if there would be anything out of the common in its melting or heat treatment. If, for instance, the heat treatment is different from that of the other alloys, the castings would have to be treated separately and this may delay delivery and increase the cost.

2. *Metal Ordering.*—When competitive conditions return, two suppliers may quote different prices for the same alloy, but it may be found that the cheaper alloy is of comparatively poor quality. The metallurgist will have all incoming metal analysed and will soon see if one supplier sends better metal than another. For example, both lots of ingots may be within the specification limits, but one may be much more uniform in composition from batch to batch than the other, and hence will give more uniform foundry and physical properties. If one supplier sends metal with iron very near the top limit, the pick-up from tools, dies, etc., may be sufficient to put the foundry scrap outside specification. It would be better to buy metal with a lower iron content, even if the price were somewhat higher. On such points as these, the metallurgist will be able to give the buyer valuable advice. When new alloys are bought or new suppliers visit the foundry, the metallurgist should always be called in to give advice. This is doubly important now that so many alloys are being prepared from refined remelted scrap.

3. *Melting Shop.*—While the actual melting should be in charge of the laboratory, the foundry will decide which alloy and how much, to order from the melting shop. If difficulties arise, because of lack of balance of the various demands, or for any other reason, the matter will be discussed between the metallurgist and the foundry foreman or manager, but whatever decision is arrived at by the foundry must be worked to by the melting shop.

The segregation of scrap and its use in the foundry in the correct proportion is of the utmost importance, and will need constant attention from the laboratory. If there is doubt about the composition of scrap it should be put on one side until its composition is known. It can often be identified by spot tests such as are described by Zurbrugg¹.

Every effort should be made to avoid the deterioration of scrap by adulteration. Some alloys such as D.T.D.298 and D.T.D.300 are made from high purity aluminium (99.7%), and the addition of a very small amount of impurity will bring their compositions outside specification and will materially lessen their physical properties. They can then only be used to adjust the composition of cheaper alloys and will, of course, be sold at the cheaper price.

Small metal boxes, clearly marked with the alloy number and its code colour, should be placed in the foundry, and spillings, etc. should be immediately placed in the correct box, instead of being mixed and sent to a refinery for reclamation as D.T.D.424 or D.T.D.428.

¹ *Light Metals*, 1928, 1, 355.

Fluxes

The use of fluxes should also be decided upon by the metallurgist. In some foundries fluxes are not used at all. In others there is a tendency to use far too much in the hope that the effects of bad melting practice can be removed simply by using flux. Whether they should be used at all, and if so in what quantities, will be decided upon by experience but conditions should be standardised as soon as possible. In the die shop, periodic washes with oxide removing fluxes will be given, care being taken to use only "modifying salts" with modified 2L33 or D.T.D.245, in order to avoid reversion.

All metal should be weighed in and out of the metal store and records should be kept of all charges. If possible, records of consumption and costs of fuel should be kept in order to assist the quotation department.

Melting Temperatures

Melting temperatures should be strictly controlled by the metallurgist. Maximum temperature should be given and should never be exceeded. This is one of the most important details in aluminium foundry work. If everybody could be convinced that the only temperature to use is the lowest which will give a good casting, the amount of foundry scrap would be materially reduced. The actual casting temperature is as important as the melting temperature, but if a high melting temperature is used, the castings will be of inferior quality even when cast at the correct temperature. In order to show the effect of high temperatures on grain size and physical properties the writer carried out the following experiment. Some virgin D.T.D.304 was melted, and test bars cast at 660°C. as soon as the metal reached that temperature. Heating was continued and bars were cast at 750°C. Heating was further continued and the metal was held at 820°C to 850°C. for half-an-hour. Two bars were then cast, taking the metal straight from the pot at 850°C., followed by two more, taking the metal from the pot at 850°C. and allowing it to cool to 660°C. in the ladle before pouring. Fig. 1 shows the grain sizes obtained under these conditions and the tensile figures obtained after heat treatment to specification D.T.D.304 are shown in the following table:—

Pot Temp. °C.	Casting Temp. °C.	Tensile Stress Tons/sq. in.	Elongation Per cent. on 2in.
660	660	19½-20	8.0
750	750	14½-15	3.0
850	850	12½-13	3.0
850	660	17-17½	4.5

D.T.D.304 specifies 18.0 tons per sq. inch and 4% elongation. It will easily be seen that the effect of casting temperature on both tensile-strength and elongation is most marked, and that after "stewing" at a high temperature, even casting at normal temperatures does not give anything like as good figures as does metal which has not been overheated.

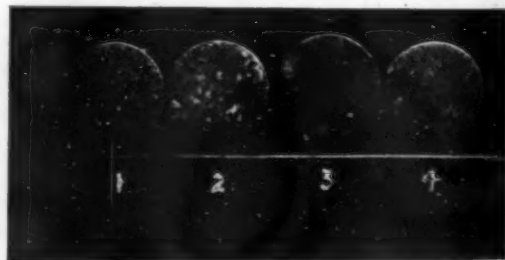
These operating temperatures are determined by means of a pyrometer, and it is of the utmost importance that they should be constantly and carefully checked by the laboratory. Bare metal thermo-couples are used and these should be kept in good condition, spares being always available.

Sometimes the scrap in one bin accumulates. In

order to prevent accidental mixture with other alloys this should be melted in as large batches as possible so as to give uniform composition from batch to batch and to minimise work in the laboratory. A batch of this kind, in fact any batch which is awaiting analysis, should have a red label tucked between two of the ingots, giving the batch number, and the assumed alloy, and reading "Not to be used." If the analysis proves to be satisfactory, this label is replaced by a white label which again gives the batch number and alloy and reads "Passed for use." If the analysis is not satisfactory a label of different colour is used which reads "To be used only under laboratory instructions." The metal position can thus be seen immediately on entering the store, and the metal of poor quality can be used a little at a time instead of being left in the store indefinitely.

4. *Foundry.*—In the foundry itself the metallurgist will be responsible for the casting temperatures, and for sand control. The correct casting temperature is decided upon for every casting being made, and all metal should have its temperature taken before it is poured, so that these casting temperatures are actually used. As the foundry manager has decided upon the size and shape of the runners, he will also decide on the temperature to be used for the first few castings. Visual and X-ray examination will enable the metallurgist to advise him whether to change it or not. When the temperature has finally been decided upon it must be strictly adhered to by the laboratory staff, whether they agree with it or not. The temperature should be entered on the foundry technique card so that it can always be referred to.

Sand control is an important job and it may be necessary to make it a full-time job for one of the laboratory staff. Moisture, green strength and permeability should be determined at regular intervals and should be entered as soon as possible on a chart which can easily be seen by those concerned. Tests carried out on new sand give useful guidance to foundry and core shop.



- 1 Melting temperature 660°C., cast at 660°C.
- 2 Melting temperature 750°C., cast at 750°C.
- 3 Melting temperature 850°C., cast at 850°C.
- 4 Melting temperature 850°C., cast at 660°C.

Fig. 1.—Effect of melting and casting temperatures on grain size.

It is also necessary to control the melting temperature in the gravity and pressure die shops. Here again the temperatures should be decided upon by the foundry manager and the laboratory staff should report to him when they are exceeded.

In both the sand and the die foundry the metallurgist must always be at the disposal of those who have

problems and who require advice and assistance.

In addition to this control work the metallurgist should be expected to try to improve the foundry technique for castings which are either giving a high percentage of scrap or are taking too much time or trouble to make, and are therefore costing too much. He should be able to have a few experimental castings made with modified runners or risers, or with any other modification which he thinks would improve them. Such castings are given a distinguishing mark and are followed through and compared with the routine castings. The moulder will no doubt want to know if he is going to be paid for these castings if the metallurgist produces scrap, and his point of view should be considered. An arrangement which the writer found to work quite well was for the metallurgist to mark the moulder's foundry card "2 off experimental" and initial it. The moulder was paid for those two castings whatever happened to them.

When the experimental castings show an improvement they are made on a larger scale, and if the improvement is confirmed, the manager is called upon to decide whether or not the new technique shall be standardised. If it is, it is entered on the foundry technique card for that job.

If scrap on a particular job is very heavy and an improvement is urgently required, the metallurgist might follow the experimental castings through the fettling and inspection departments, in order to try to speed up the improvement. This plan has its disadvantages however. A large number of "bits and pieces" in various parts of the foundry cause confusion, and work on the satisfactory jobs is seriously delayed. Again, the overheads on these "specials" become abnormally high as staff have to be told off to follow them about. Overtime will probably have to be worked to get the rest of the castings away. Unless therefore, the matter is of vital importance, such as a prototype part for a new aircraft, the experimental castings should be specially marked and specially reported upon by those concerned. They will go through easily and reasonably quickly and can be personally inspected by the metallurgist at any stage if necessary.

5. *X-ray*.—The metallurgist will generally be in charge of the X-ray department and it is one of his most important duties to let the foundry know as soon as possible whether the first few castings of any new job are satisfactory or not. This applies, of course, to both the sand and the die foundry.

Aircraft castings are divided into three classes. In Class I. are castings which would cause an aircraft to become out of control if they failed. In Class II. are castings which will be highly stressed, but would not cause the aircraft to become out of control if they failed. In Class III. are the unstressed or lightly stressed castings. All Class I. and Class II. castings must be X-rayed until a satisfactory foundry technique is obtained, and this is deemed to be so when 20 consecutive castings show satisfactory radiographs. The foundry and the inspection department are then notified that radiological approval of that casting has been given and subsequently no alteration whatever must be made to the foundry technique. The date of radiological approval should be entered on the foundry technique card.

When radiological approval has been obtained, fewer

castings will be radiographed, the number depending upon the class to which the castings belong. If the radiographs begin to show defects the foundry and inspection are immediately informed that approval may be withdrawn. If the trouble persists, approval is withdrawn and the 20 consecutive good castings have to be obtained again. In this way a constant watch is kept on the quality of aircraft castings.

Class III. castings need not be X-rayed but most foundries will no doubt examine representative castings under the fluorescent screen and will radiograph doubtful ones.

Apart from the necessity of complying with A.I.D. regulations, it is most important that the foundry manager should know as soon as possible whether or not the first few off are satisfactory. In mechanised foundries a large number of castings are being made from comparatively few patterns, and if anything goes wrong, a large number of scrap castings may be made in a short time. The first half dozen or so from each pattern should therefore be X-rayed every morning, and in order to save time should be only rough-fettled. This radiological control should also be applied to gravity die castings.

If faults are found by X-ray examination, the castings should be sectioned in the laboratory and carefully examined. The type and shape of the failures may throw a good deal of light on their cause, and may enable the fault to be remedied quickly.

When castings are being radiographed for final inspection all previous radiographs which have been taken for foundry guidance are ignored. Faults may have developed because of heat treatment or mishandling and while many of them could be found by visual examination, it is nevertheless essential that as far as inspection is concerned, the casting must be in such a condition when it is radiographed that all defects which could be present actually are present, and none can develop after radiography.

6. *Test bars*.—The provision of tensile test bars and analytical samples is another important duty which the laboratory has to carry out. These are essential for the release of A.I.D. controlled castings, but in addition, samples will be required in order to enable routine control to be carried out on the quality of the metal. If, for example, a batch of metal appears on analysis to have been slightly adulterated, steps can be taken to determine the source of the adulteration or to change over to a new batch of metal so as to avoid making castings which are outside specification as regards composition.

To obtain analytical samples there are two alternatives. In some foundries, small blocks of metal, say 2 in. \times 1 in. \times 1 in. are cast in an iron die. These can easily be stamped up and drilled, and take up little room when stored. Other foundries prefer to use the test bar head for the analytical sample on the ground that the metal analysed is actually that which gave the recorded tensile result. There may be occasions when it is useful to know this.

Close attention must be paid to the preparation of test bars because of their bearing on the ultimate fate of the castings. If the test bars fail there is quite a chance that the castings will be scrapped, and if the cause of the failure is bad quality of the test bars, the scrapping of a batch of perfectly good castings is little short of a disaster.

Both the method of casting and the shape of the test bars are laid down by A.I.D. and B.S.I. specifications. A drawing is given showing the shape and size of the bar and the size of the tube in which it is moulded. Dried sand moulds are used but in the case of 2L33, chill moulds may be used if die castings are made. The results will then have to conform to the specification for chill cast bars. All other die castings are covered by sand cast bars.

When specifications were drawn up for the first aluminium foundry alloys, a test bar with a comparatively small head was used. This gave satisfactory results for these alloys and is still used for 2L33, 3L8, 4L11 and 3L5. Later however, new alloys were introduced which required more efficient feeding, and a test bar was specified with a much bigger head, the bar itself being the same size as before. The new type of bar is always specified now, although for D.T.D.424 and D.T.D.428 both types are shown in the specification and either may be used.

The quality of the test bar moulds has a definite influence on the quality of the bars and plenty of well-dried and cooled moulds should always be in stock. On one occasion one alloy gave poor test bar results and a great deal of work was carried out to discover the reason. It was eventually found that when the charge-hand made the moulds the bars were satisfactory, but when the usual girl made them, the results were poor. Such cases are rare, but they show that the greatest care should be taken to obtain consistently good moulds.

Close attention should also be given to the casting of the test bars. A casting temperature should be decided upon for each alloy and this should be strictly adhered to, the people who cast the bars being given the correct temperatures in writing. Admittedly a variation of 30° C. or so will not appreciably effect the quality of the bar, but if this is allowed the variation will soon be much bigger and the effect will be appreciable, as already pointed out.

According to the specification, the bar should be tilted at an angle of 30° from the vertical when pouring starts. The exact method of pouring is not specified and it varies in different foundries.

Some time ago enquiries were made as to how test bars were cast in neighbouring foundries. The following variations were found:—

1. The bar was poured slowly and left in its original position.
2. The bar was poured slowly and gradually brought to the vertical position before the finish of the pour.
3. The mould was tapped during pouring in the belief that a little vibration gave a sounder bar.
4. Lack of vibration was considered to be so important that if somebody walked past while the bar was being poured it was scrapped.

All these methods were said to give satisfactory results. The only point in common was that pouring was invariably done steadily and slowly, and this would appear to be the one essential for the production of a good test bar, assuming of course, that the casting temperature is correct. The metal should be poured in a stream about $\frac{1}{2}$ in. thick and the continuity should not be broken. If it is, the bar should be scrapped, as it may have a cold shut. The time taken to fill the parallel part should be about 15 seconds. The head can be filled up more quickly so that the feeder metal is hot.

When 2L33 is to be tested, it is a good plan to cast an extra bar, to cut it about one-third the way through, and then to break it, before the metal is poured. If the fracture shows the modification to be unsatisfactory, the condition of the metal can be corrected and another set of bars taken. If this procedure is always carried out, the technique of modification will soon be mastered and under- or over-modified melts seldom found.

When castings are made for the War Office or Admiralty, chill cast bars may be specified. The standard A.I.D. mould is used, as specified before and moulds were used. It is poured at an angle of 30° from the vertical like sand cast bars, and the mould temperature must be 100° to 120° C., largely to ensure that it is quite dry. If a melt of say Y alloy is used for castings for both the Air Ministry and the Admiralty, it will be necessary to take a set of sand cast bars for the Air Ministry and a set of chill cast bars for the Admiralty.

All bars are stamped with the hatch number and the alloy. Those which do not require heat treatment may be turned at once and pulled. Those which have to be heat treated will be placed in racks until the castings are ready and will then be treated with the castings and tested.

7. *Heat treatment.*—Heat treatment requires extreme care and technical knowledge, and is definitely a laboratory job. Records must be kept in such a way that they can be referred to and understood months after the actual treatment was given. The laboratory must work in close collaboration with the progress department in order to try to treat the most urgently wanted castings first. As the times and temperatures used for the various alloys differ somewhat, this is not always easy. When the department first starts up, or when new heat treatment furnaces are installed, experimental test bars should be given different treatments within the limits of the relevant specifications, in order to find the conditions which give the best results. These should then be standardised for each alloy. The necessity for these trials can easily be seen by reference to specifications D.T.D.304 and D.T.D.361. These cover the same alloy. The heat treatment temperatures specified are also identical but differences in the times give appreciable differences in the physical properties, as shown below:—

Specification	Solution Treatment		Precipitation Treatment		Specified Tensile Figures	
	Temp. °C.	Time	Temp. °C.	Time	Ult. Stress tons/in. ²	Elongation % on 2 in.
D.T.D. 304	525-545	12-16 hrs.	160-170	12-24 hrs.	18	4
D.T.D. 361	525-545	16 hrs. (min.)	160-170	8-16 hrs.	21	1

It will be seen that according to the specifications, 16 hours at 535° C. and 14 hours at 165° C. may be expected to give either 18 tons/in.² and 4% elongation, or 21 tons/in.² and 1% elongation. Trials as suggested above will show what treatment should be given to the material in use to give the physical properties required.

8. *Final Inspection.*—The metallurgist should keep in close touch with final inspection, to make sure that heat treatment is not causing distortion of awkwardly-shaped castings. As he will sign the A.I.D. release notes he should also make sure that the general appearance of the castings is satisfactory.

9. *A.I.D. Release Notes.*—As chief inspector, the metallurgist will have to release every casting made

for aircraft. Special release notes, the wording of which is laid down by A.I.D. have to be signed in duplicate, one copy being sent to the customer and the other retained. They are really a certification that the castings have been made and tested in accordance with the relevant A.I.D. specification and are considered to be satisfactory in every way.

10. *Laboratory work.*—So far, all the duties of the metallurgist which have been mentioned have been in the works, but a good deal of organisation and supervision will be called for in the laboratory itself. It will be necessary to organise the routine analysis of samples for control and release purposes and also of samples of incoming metal. Batches of metal which are thought to have been adulterated or which are giving poor quality castings will probably require special attention. If the foundry is big enough to justify the expense, a spectrographic outfit would speed up the routine work considerably. A spekker would also be found useful and polarographic analysis is gradually coming into use². For a large proportion of the routine work, speed is far more important than scrupulous accuracy. For instance, the foundry manager wants to know whether or not the copper content is within the limits of 1% to 3%; he is not in the least interested to know whether it is 1.230 or 1.235%, as this difference will not have the slightest effect on the casting and will be more than covered by segregation. If then, the metallurgist can use a method which is not quite so accurate but much quicker, he should do so. For research work of course, the greatest possible accuracy should always be aimed at.

Routine macro and micro examination is also very helpful. Macro etching of cast rod, rolling slabs, ingots, etc., enables a control to be kept on casting conditions and if a mottled effect has been obtained on radiography, macro etching will show whether or not this is due to large grain size.

Micro examination may also be very informative. Porosity may be investigated and sections of cracked or faulty portions examined to see how far the fault penetrates and what difference is made by a change in foundry technique.

Keller and Wilcox³ have published photographs of 20 different constituents which may be found in aluminium alloys. In each case a binary alloy was made, using the purest materials available and the same field on a polished sample was etched with each of six different reagents. The reagents used and the results obtained are given in table form. A similar table suggested by Dix is given in Berghlund's "Metallographers Book of Etching."

Another part of the laboratory routine work is the pulling of test bars. The dimensions of the standard bar are given in A.I.D. and B.S.I. specifications, and the bars should have a very good finish, as aluminium alloys are notch sensitive and a bar with prominent tool marks may give poor results because of the tool marks.

Inspection Routine

Whether the metallurgist is the chief inspector or not, it is his duty to investigate the cause of any defects which are reported as due to faulty metal, and he should always be in close touch with the inspection department in all parts of the works.

Inspection starts as soon as the castings are knocked out, and is not completed until they are ready for despatch. Its purpose is to throw out defective castings as soon as faults are seen so as to avoid wasting time and energy in finishing them. In some cases, they will be repaired and afterwards returned to their batch, but even so they should be taken out of the normal fettling routine as soon as possible.

The first stage of inspection is called "rough inspection" and its purpose is to remove castings which are obviously defective and are not worth fettling. Misplaced cores, giving uneven wall thickness, blow holes, sand inclusions, draws, or sinks are some of the faults which would be seen and would necessitate the withdrawal of the casting.

Careful records of this scrap should be kept and copies should be sent to the progress department, the foundry manager, and the metallurgist, who will then be able to see if the order is being held up by some persistent defect; and whether it is foundry trouble or a metallurgical one, it can be investigated immediately.

The reason for rejection is shown in this scrap report by means of code letters. While there should be enough of them to enable the inspector to differentiate between the various causes of failure they should not be so numerous as to become confusing. The following code is suggested for the sand foundry, but individual foundries would no doubt add to or subtract from it.

B.—Blowhole. Caused by gas or steam escaping from sand. Sand too wet, or cores not sufficiently vented.

C.—Cracks. Metal may be unsuitable for the job. Sand may be too strong. Casting temperature may be too high. Casting may have been knocked out too roughly or while still too hot.

C.J.—Cross jointed. (Top half not registering with bottom half.) May be due to bad pattern, loose pins, or too hard rapping.

C.M.—Core missing.

D.—Drawn metal. Draw or sink caused by lack of feed.

K.—Damage during knock out.

M.—Misrun. Metal has not filled the mould. Casting temperature too low or ingate too small. Possibly an air lock. Cold shuts could be included under this heading.

M.C.—Misplaced core. May be due to poor core design, or insufficient print, or by careless coreing up.

P.—Porosity. Probably due to careless melting practice.

S.—Scab. Caused by local hard ramming and displacement of sand by steam pressure behind it.

S.I.—Sand in. Sand trapped in metal, or holes where sand has been. Careless moulding.

W.A.—Wrong alloy.

Casting defects may be roughly classified under core shop, pattern shop, foundry and metallurgical defects, and the foundry manager should be informed as soon as there is a tendency for any one defect to become serious. It may be found that the defect is not due to the cause at first thought and that is why the foundry manager is probably the only person who can put it right. For instance, a badly shaped core may start enquiries in the pattern shop, but it may be found that the cores are being removed from the box carelessly or are allowed to sag on their way to the drying oven.

In the die foundry the codes might be as follows:—

² See "Spectrochemical and Polarographic Analyses of Aluminium," British Aluminium Company.

³ Polishing and Etching of Constituents of Aluminium Alloys, *Metal Progress*, 1933, 23, 38.

B.—Blow-off mould. Metal sometimes "rides" over surface with no coating or with smooth coating.

C.—Cracks. May be unsuitable alloy. Cores may be removed too late. Pouring temperature may be too high.

C.M.—Core missing. Small cores are sometimes forgotten.

D.—Draw or sink caused by lack of feed.

K.—Damage during knock out.

M.—Misrun (including cold shut).

W.A.—Wrong alloy.

It is of the utmost importance that information regarding faults should be passed on as quickly as possible so that a tendency can be checked while it is still a tendency, and before it becomes an established fact. In the case of regular running jobs it will probably be worth while to introduce a system of statistical quality control.

It will sometimes be found that when risers are cut off a fault is noticed which could not be seen before. In these cases it may be necessary to inspect before and after fettling, or if very few faults are seen before fettling, to omit the first inspection and examine the castings only after rough fettling.

Final inspection is carried out after the fettling has been completed, and any heat treatment required has been carried out. Radiography is also carried out at this stage. The exact routine will be decided upon by the chief inspector. If the surface is satisfactory and no defects are seen, but a large proportion of the castings show blow holes or other defects under X-ray, it will probably be better to view them on the fluorescent screen before visual examination, in order to avoid the inspection of a large number of defective castings. On the other hand, if a large proportion of heat treated castings have developed cracks which are not visible under X-ray, it is better to inspect them first in order to remove defective castings and then to X-ray only the good ones.

Special Tests

Sometimes special tests are asked for by the customer. For instance, a pressure test may be required. Steel plates with rubber sheet to act as seals are clamped on to all openings in the casting and to a nipple fixed to the middle of one of these a tube is fixed through which gas at a specified pressure may be introduced into the casting, which is immersed in water. Leakage is shown by bubbles. It is found that if castings are gas tight at say 30 to 30 lb./in.² they will generally be so at any pressure which is likely to be asked for.

Sometimes a less drastic test is applied. A brightly coloured dye dissolved in a penetrating solvent is put inside the casting, which is either allowed to stand, or is subjected to a little air pressure inside. Leakage may easily be detected because of seepage of the dye.

Other tests for detecting cracks or porosity are the chalk test and the fluorescent test. For the chalk test the castings are heated for 20 to 30 minutes at 95° C. in a bath of paraffin and lard oil. Any cracks will have opened owing to the expansion of the metal, and will have allowed the penetrating oil to enter. The castings are then taken out, dried, and rolled in French chalk, which gives them a white coating. They are then allowed to cool. Contraction of the metal squeezes the oil from any cracks present and this wets the French chalk and produces dark marks which show up the defects.

The fluorescent test consists in immersing the casting in a hot fluorescent liquid for 10 or 15 minutes. They are allowed to drain and are then immersed in carbon tetrachloride which washes the fluorescent liquid from the surface. When cool and dry they are examined under ultra violet light. If any of the fluorescent liquid has seeped from a defect it appears bright green.

Whichever tests are used to enable the inspector to decide whether to pass or reject the castings, they should also be used to guide the foundry. It will soon be seen whether any defect occurs so infrequently that it may be termed accidental or whether it persists. If it does persist the foundry should be notified and the casting should be X-rayed and subjected to full metallurgical examination in order to find the reason for the failures.

It will be seen from the above that the laboratory is a very important part of an aluminium foundry, which can help in a multitude of ways to produce better and cheaper castings. Most foundries will agree that scientific assistance in the foundry itself as described, will help the industry to enter new fields and make its presence felt more and more in the provision of new aids for the comfort and prosperity of our people.

Readers of the above article will be interested to learn that Charles Griffin & Co. Ltd., are shortly publishing a book by the author entitled "Aluminium Alloy Castings: Their Founding and Finishing."

Price of Aluminium

The Minister of Supply has announced that the price of virgin aluminium in ingot or notch bar form is now increased from £67 to £72 15s. 0d. per long ton delivered into consumers' works.

The new price applies to metal of a purity of 99% to 99.5% inclusive, with premiums as follows for higher purities:—

Purity	Price per ton		
	£	s.	d.
Minimum 99.6%	80	15	0
" 99.7%	84	15	0
" 99.8%	89	15	0
" 99.9%	122	15	0
" 99.99%	172	15	0

This increase in price is consequent upon the cost of metal under the Ministry's Canadian contract having risen on account of the change in the rate of exchange.

Restoration of British Property in Yugoslavia

CLAIMS by British owners of property for the restoration to them of the control of their property in Yugoslavia will be dealt with by the Mixed Commission which, as already announced, has been set up in Belgrade.

In order to facilitate the work of the United Kingdom Representative in presenting and pursuing claims for such restoration, a Register of British property in Yugoslavia is being established. Persons having title to property as defined in paragraph 6 should register their claims in accordance with the following arrangements, to ensure that they receive due consideration.

The Register will be kept in the Trading with the Enemy Department, 24, Kingsway, London, W.C.2, to which address application should be made for the appropriate forms.

Grain Boundary Penetrations by Liquid Metals

II.—Attack of Platinum Alloy Sparking Plug Electrodes by Molten Lead

By P. J. E. Forsyth, S.I.Mech.E. and W. R. Smith, B.Sc.

Metallurgist, Royal Aircraft Establishment, Farnborough.

Grain boundary penetration by a molten metal is not uncommon in present-day engineering practice and, since such penetration does destroy the intercrystalline cohesion of an alloy, premature failure can and does occur from this cause. The susceptibility to penetration of an alloy depends upon the nature of the alloy and of the liquid metal in contact with it. In this article are discussed two forms of lead attack on sparking plug electrodes.

THIS paper deals with two forms of lead attack experienced on sparking plug electrodes made from platinum alloy wire; the general alloying attack and the grain boundary attack, both of which have been observed by microscopic examination of electrodes which have failed under severe service conditions.

The practice of using leaded fuels in aircraft engines has been the cause of failure of the sparking plugs due to lead attack of the platinum alloy electrodes. During combustion, a large proportion of the lead in the fuel is converted to lead oxide and lead bromide and these two compounds form a series of oxy-bromides such as $PbO.PbBr_2$, $2PbO.PbBr_2$ and $4PbO.PbBr_2$ as shown in Fig. 1, which is the freezing point diagram for mixtures of lead oxide and lead bromide. Some of these lead compounds will be deposited at the tips of the electrodes where they are reduced to metallic lead. The products of combustion in the engine cylinder will contain powerful reducing gases such as carbon monoxide and hydrogen which convert the lead compounds into metallic lead at relatively low temperatures, e.g., $100^\circ C.$ for carbon monoxide and $310^\circ C.$ for hydrogen.

Lead will readily alloy with platinum and therefore straightforward diffusion of the deposited lead into the platinum alloy electrodes may take place with the formation of one or more new phases. The equilibrium diagram of the lead-platinum series of alloys is shown in Fig. 2.

The newly formed phases may recrystallise at the working temperature of the electrodes or may even be completely molten. Fig. 3 shows a recrystallised

area near the tip of an electrode, and also shows the formation of the lead-platinum eutectic. The extent of the lead diffusion is indicated by the fact that in this case, the recrystallised area, consisting of large equiaxed grains (arrow A), extended a considerable way in from the electrode surface.

It was in this recrystallised area that grain boundary penetration by the lead recorded in Figs. 4 and 5 was observed. It can be seen from Figs. 6 and 7, however, that grain boundary attack can take place in the original cold worked structure of these alloys, and this is possibly the more common form of attack. The lead penetration may completely destroy the cohesion of the grain, causing distortion and sometimes complete fracture of the electrodes when subjected to the cyclic stresses experienced in service.

The attack will start from deposits of molten lead on the surface of the electrode and may penetrate either the recrystallised grain boundaries as in Figs. 4 and 5 or the grain boundaries of the original cold worked

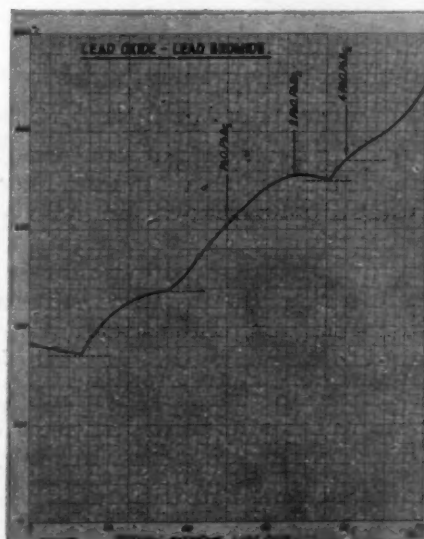


Fig. 1.—Drawn from data from the International critical tables, Vol. IV, p. 50, After Sandonnini

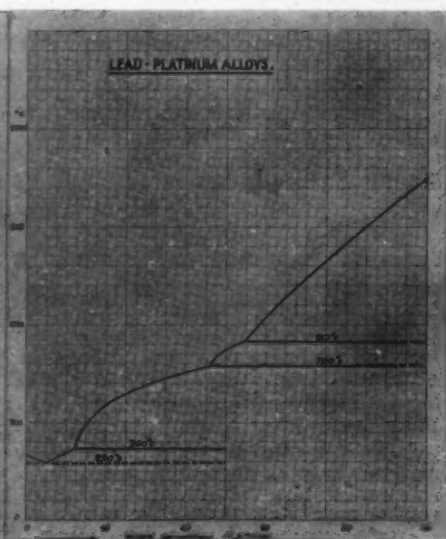


Fig. 2.—Drawn from data from the International critical tables, Vol. II, p. 415. After Doerinkel



Fig. 3.—A recrystallised area near the tip of an electrode. $\times 1500$.



Fig. 4.—Grain boundary penetration by lead. $\times 1500$.

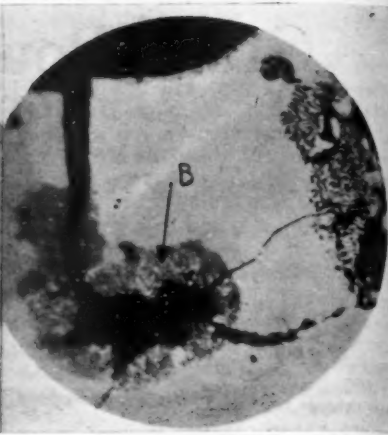


Fig. 5.—Grain boundary penetration by lead. $\times 1500$.

structure. It can be seen in Figs. 4 and 5 that the penetration along the grain boundaries is accompanied by diffusion towards the centre of the grains with the formation of a second phase grey in colour indicated by arrows B. No eutectic structure appears in these areas because the concentration of lead in the platinum has not been enough to cause liquation at the working temperature of the electrode at these places. At the tip, however, where there was more free lead and where the temperature was no doubt higher, areas of the eutectic were observed.

There seems to be no doubt that as in other types of liquid metal penetration the presence of stress either applied or internal is necessary for this phenomenon to occur and the release of this stress by cracking will cause distortion. In Fig. 5 the displacement of the grain is indicative of the internal stress in the material.

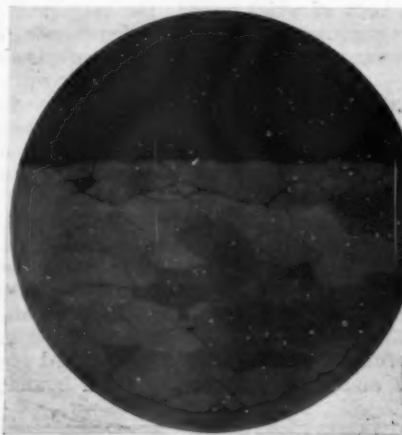


Fig. 6. $\times 250$. Grain boundary attack in the original cold worked structure of platinum alloy.

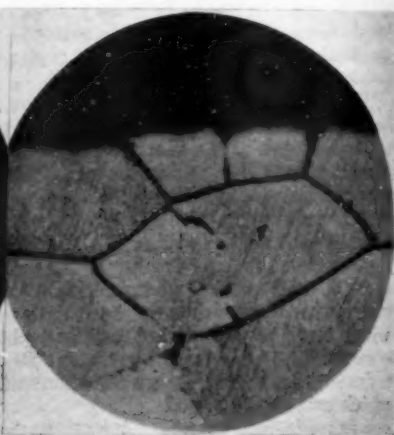


Fig. 7. $\times 1500$.

This form of intercrystalline penetration differs from those described by the authors in Part I of this paper in that the lead is soluble in the platinum which it attacks, whereas in the other cases the penetrating metal had negligible solubility in the matrix.

Australian Developments

DIFFICULTIES encountered during the war, through lack of available supplies or transport, caused the Broken Hill Proprietary Co., Ltd., Australia, to construct a ferro-alloy plant at Newcastle, which has supplied all the company's tungsten-carbide requirements, as well as all its wartime alloy needs. According to information received, the company is also considering developing ore resources in New Caledonia, and several sites are being tested to determine the suitability of the ores.

It is noteworthy that this Australian steel plant used 1,364,141 tons of iron-ore from several small deposits in New South Wales, to counteract the deficiency caused through lack of shipping.

Civil Aircraft Orders

FOLLOWING a recent review of future requirements of civil aircraft, substantial additional production orders will shortly be placed for various new types of British aircraft at present under development and required for the future services of the three public Corporations. Negotiations have been opened with the firms concerned with a view to the purchase of over 200 in all of these aircraft of the future. Whilst these negotiations are in progress it is not possible to disclose the particular numbers and types, but further announcements will be made from time to time. These aircraft will be in addition to more than 300 civil aircraft of types already in service or shortly coming into service.

Some Recent Appointments and Staff Changes

DR. EDWIN GREGORY, Ph.D., M.Sc., F.R.I.C., and BRIGADIER ARTHUR LEVESLEY, O.B.E., M.C., M.I.Mech.E. have been appointed Directors of Edgar Allen and Co., Ltd., Imperial Steel Works, Sheffield, 9.

Dr. Gregory, who joined the company in August, 1944, as Chief Metallurgist, was educated at the old Sheffield Central School and the University of Sheffield, gaining the associateship in metallurgy and the Mappin Medal and Premium; in addition to other awards, he obtained the Sheffield Manufacturers Prize. He has had a wide experience first at Kayser, Ellison and Co., Ltd., and later on the permanent staff of the Metallurgical Department of Sheffield University. In 1937 he was appointed Chief Metallurgist to the Park Gate Iron and Steel Co., Ltd., and in 1943 he became Assistant Director in charge of the Metallic Materials Section of the Aeronautical Inspection Directorate of the Ministry of Aircraft Production.

Brigadier Levesley joined the staff of Edgar Allen and Co. in 1910, and became technical assistant to the works engineer. In 1928 he took up an appointment with Hopkinsons Ltd., as Sales Engineer, covering South Yorkshire, and later including Staffordshire and Derbyshire. In 1935 he became assistant to the Managing Director of this company. In 1939, when war broke out, he was embodied with the Territorial Army in his rank of Lieut-Colonel in command of No. 9 Army Field Workshop. After considerable service his active career in the British army ended in 1945, and he was appointed foundry manager of Edgar Allen and Co.

MR. H. GRAY, Chief Draughtsman of the engineering department of Edgar Allen and Co., Ltd., has retired and Mr. A. Wadsworth, of the British "Rema" Manufacturing Co., Ltd., a subsidiary of Edgar Allen and Co., has been appointed to fill the vacancy.

DR. M. L. BECKER has now taken up his appointment as Superintendent Metallurgist to the British Iron and Steel Research Association. Until recently Dr. Becker held the position of Chief Metallurgist to the Gear and Tool Divisions of Messrs. David Brown and Sons (Huddersfield), Ltd. Previously he was on the staff of the National Physical Laboratory. Earlier in his career he was Investigator to the British Cast Iron Research Association, and studied at both Sheffield and Manchester Universities.

Dr. Becker brings broad interests and experience to the service of the Research Association, and, as Head of the Metallurgy Division, he should find ample scope both in relation to the existing programme of work on alloy steels for which the Association hence forward assumes responsibility, and in connection with the contemplated expansion in allied fields of investigation.

MR. J. E. PARTON has resigned his appointment as Senior Scientific Officer with the British Iron and Steel Research Association, to become Lecturer in electrical engineering at Glasgow University.

MR. G. W. ALLOTT has been appointed Assistant to the Managing Director (engineering sales) of Newton, Chambers and Company, Ltd.



SIR ARCHIBALD F. FORBES has been appointed Chairman of the National Iron and Steel Board. He is a chartered accountant, and since 1935 he has been Managing Director of Spillers, Ltd., and Director of several other companies. He was educated at Paisley Grammar School and Glasgow University. He was a member of various Reorganisation Commissions and Committees appointed by the Minister of Agriculture, 1932-39; Director of Capital Finance, Air Ministry, 1940; Financial Under-Secretary, Minister of Aircraft Production, 1940; Deputy-Secretary, 1940-43; Controller of Repair, Equipment and Overseas Supplies, 1943-45; Vice-Chairman of Air Supply Board, 1940-43, and of Production Committee, 1941-42; Member of Aircraft Supply Council, 1943-45.

MR. N. NICHOLSON has retired from the position of Managing Director of J. J. Habershon and Sons, Ltd., of Rotherham. He will continue as a Director. Mr. P. J. Habershon becomes Managing Director and continues as Chairman of the company.

AFTER 17 years with the Bureau of Mines, in which he rose from Chief Engineer of the Metallurgical Division to Assistant Director, Dr. R. S. Dean leaves Government service to re-enter private business.

As Head of the Metallurgical Division of the Bureau, Dr. Dean has been responsible for the initiation of the Bureau's work in pure metals, including electrolytic manganese, electrolytic chromium, ductile titanium, cobalt, zirconium, etc. He also personally directed a programme of alloy development based on these metals as well as work on magnetic separation and new flotation reagents.

Dr. Dean will continue professional work in Washington, already having commissions for research and development in electrometallurgy and alloys. These are fields in which he was especially active both while in Government service and in private industry.

MR. BRUCE H. LEESON, O.B.E., M.I.E.E., has been appointed by the Council of the British Electrical and Allied Manufacturers' Association to be Director of the Association as from October 1, 1946, in succession to Mr. V. Watlington.

LT.-COL. S. C. GUILLAN, who recently resumed his duties as editor of the Journal of the Institute of Metals, has been appointed Assistant Secretary of that Institute. Mr. A. E. Chattin, who has been performing dual duties for some time, reverts to his duties with the Iron and Steel Institute. Major W. G. Askew, M.C., has been appointed assistant editor of the Journal of the Institute of Metals in place of Mr. N. B. Vaughan, who has joined the staff of the Aluminium Development Association.

MR. A. JOHNSON, late of the Eyre Smelting Co., Ltd., has been appointed representative in London and Southern England for Oakland Metal Co., Ltd., metal alloys manufacturers of Willington, Derbyshire.

MR. WALTER W. STEVENSON, F.R.I.C., F.I.M., assistant director, Research and Development Department, The United Steel Companies, Ltd., has been appointed chief metallurgist to Dorman, Long & Co., Ltd. Receiving his early metallurgical training at the Brown Firth Laboratories under the late Dr. W. H. Hatfield, Mr. Stevenson was appointed chief chemist of these laboratories in 1927. Five years later he joined the late Dr. T. Swinden as head of the chemical section in building up the Central Research Department of the United Steel Companies. Last year Mr. Stevenson became assistant director of the Research and Development Department, acting as liaison between the Company's central laboratories and branches with particular reference to coke ovens, blast furnaces and mass production of steel-making plants.

MR. L. C. MONTAGUE, A.C.I.S., has been appointed a Joint Managing Director of Johnson, Matthey & Co., Limited, as from August 28th, 1946. Mr. Montague has been associated with Johnson, Matthey & Co., Ltd., for 27 years and has been Secretary to the Company for the past twelve years.

Reviews of Current Literature

Deformation and Fracture of Metals under Static and Dynamic Loadings

ALTHOUGH a considerable amount of work on practical and theoretical problems connected with the mechanical behaviour of metals has been carried out in Russia, most of the results are published only in the Russian language, and, in some cases, in journals hardly obtainable abroad. One result of this is that the field covered in reviews of research progress written by British and American authors tends to be incomplete through the omission of reference to the work of Russian engineers and physicists. On the other hand, similar reviews published in Russia do not suffer from a handicap of this kind, for the authors seem to be as familiar with the publications of all other countries as with their own. Thus, they have the materials ready to hand for a more comprehensive assessment of current ideas on almost any scientific subject than is likely to be possible elsewhere until the study of the Russian language becomes much more common than it is at present.

This book by Fridman is a case in point. Its main object is to present the author's views gained during several years' experience and research on various aspects of the mechanical testing of metals at the Aviation Materials' Institute, Moscow, but throughout the book their relation to previous work is discussed in detail, and valuable summaries of results, particularly of Russian and American investigators, are given, there are 229 references covering the period up to 1944 and part of 1945.

Fridman is the author of many papers which have appeared in the *Journal of Technical Physics* (U.S.S.R.), *Zavodskaya Laboratoriya*, and other Russian journals; he has also published certain monographs, such as "A Unified Theory of the Strength of Materials." The main results of the earlier works are included in the present book, but on the theoretical side they have been amplified, and, to some extent, amended. The final chapter puts forward proposals of a practical nature for increasing the value of mechanical testing and methods for improving the strength of metals. The whole subject is, however, according to the author, still in its initial stages of growth, and only a few of the simpler problems can be considered as solved. The book does not touch upon wear, fatigue, creep, and other complex forms of deformation and fracture.

In Fridman's treatment great importance is attached to the properties associated with the resistance of a material to fracture. This is represented by the final ordinate on stress-strain curves, and not by the limit of strength, or ultimate tensile stress, as normally measured in tensile testing. The author uses true stress-true strain curves, based upon Ludwik's generalised flow curves, in which maximum shear stress is plotted against maximum shear strain. He argues that every material has two basic fracture properties—rupture and shear strength. Rupture is explained by means of the maximum strain theory of strength, presented in a new form as the maximum induced stress theory, wherein expressions involving Poisson's ratio are used to inter-relate tension, torsion, and compression failures through rupture. Shear fracture is explained on the basis of the maximum shear stress theory.

The stress state varies with the type of loading, and is characterised by a coefficient α , which is the ratio of t_{\max} , the maximum true shear stress, to S_{\max} , the maximum true induced normal stress. For shear and torsion states, $\alpha = 0.8$; for tension of un-notched specimens, $\alpha = 0.5$; for compression, $\alpha = 2$; and for compression with side pressure, such as occurs in indentation tests, $\alpha = \infty$. In the case of notched specimens, tested in tension, or within the neck of a ductile test-piece, $\alpha < 0.5$. A "diagram of mechanical state" is constructed with axes, t_{\max} and S_{\max} , and the stress states are represented graphically by means of lines drawn from the origin with slopes corresponding with the various values of α . These radial lines intersect other lines, specific to the material being studied, which are parallel with the axes, and represent three of the four basic mechanical properties as conceived by Fridman—viz., yield strength, rupture strength, and shear strength. The fourth basic property, the work-hardening coefficient or modulus of plasticity is provided for by the construction of a true stress-true strain curve.

These conceptions have enabled Fridman to study in a rational manner the various factors which influence the plasticity and cold-brittleness of metals and alloys. He indicates how the existence of two fracture strengths

and the transition from the one type of fracture to the other (rupture to shear) explain many experimental facts, and how their recognition leads to the discovery of new facts. Thus, alloys based on magnesium and zinc which are brittle at 20°C. and α -iron, which is brittle at -195°C., show an increase of plasticity as the grain-size is reduced and the concentration of solid solutions is raised, while many aluminium alloys, magnesium alloys at 300°C., and iron alloys at 20°C. which are ductile, show a decrease of plasticity under corresponding conditions. Evidence is given that metals and alloys which crystallise in the face-centred cubic pattern may possess inter-crystalline cold brittleness in spite of high static plasticity and viscosity at 20°C. These include certain aluminium alloys, austenitic steels, and copper alloys. The cold brittleness of technical cast aluminium is connected with inclusions, etc., at the grain boundaries; aluminium of sufficient purity (99.98% Al) does not show cold brittleness.

In connection with resistance to plastic deformation, Fridman points out that this should be assessed not from the yield-point or proof-stress alone, as is normally done, but from the proof-stress together with the modulus of plasticity, or at least from two proof-stress results referring to different residual elongations. Thus, "chromansil" steel annealed at 200°C. has a 0.01% proof stress, which is less than that of the steel annealed at 500°C., while the 0.2% proof-stress is greater in the former case than in the latter; again, duralumin type alloys are stronger than magnalium-type alloys at small deformations, but the difference tends to disappear at greater deformations, particularly as the magnesium content of the latter type is raised.

The effect of notches in specimens for tensile tests has been the subject of much study in Russia. It is interesting to note that a criticism of Kuntze's conception of cohesive strength was made by Davidenkov, in 1936 ("Dynamic Testing of Metals"), several years before similar criticisms were made independently by various American scientists (Gensamer, McAdam). Kuntze proposed an experimental method of determining the resistance to rupture of ductile materials based upon finding the effect of the strength produced by notches with varying width and sharpness and extrapolating the results to a condition of tri-axial tension in which plastic deformation would be impossible. Davidenkov showed that all-round tension was created only in the interior of the specimen, while the third principal stress was unavoidably absent on the surface; hence, plastic deformation could not be prevented in the surface layers outside the limits of elastic deformation. Kuntze failed by his method to observe differences in the rupture strength of coarse- and fine-grained iron containing 0.15% of carbon, but Davidenkov and Vitman in 1937 were successful in indicating the difference by testing the specimens in liquid air.

The testing of notched samples led Sachs and others in America to the discovery that the static constructional strength (the strength of a manufactured part) of certain steels having high tensile strengths (greater than 200 kg./sq. mm.) was much less than that of steels of medium strength (120 kg./sq. mm.). Fridman discusses various methods of increasing the strength of parts by changes in the mechanical properties of the materials used, and he gives the following examples: (a) The use of weakly-deformed and cast materials. Since with increase of the degree of deformation the

longitudinal resistance to fracture increases while the transverse falls in comparison with the cast or undeformed material, it may happen that in the case of parts subjected to tri-axial tensile loads the greatest strength may be obtained by the use of only weakly-deformed or even-cast materials—e.g., cartridge cases are stronger as castings than as stampings. (b) The creation of a soft surface layer. Theoretical reasoning shows that redistribution of stress is a favourable strength factor. This may be achieved by causing a soft surface layer, with low yield point, to be formed on the surface of an article. Thus, Sachs, Lubahn and Ebert succeeded in showing that surface decarburisation greatly increased the notched strength of sharply-notched tensile test-bars: Schapov (1944) found that springs used in railway transport were less liable to fracture when they were given a decarburised layer; and Davidenkov's work (1938) showed that the impact value at 20°C. was raised and the critical brittleness temperature lowered when a soft surface layer was present. Hence, for parts working mainly under static and dynamic loading the deliberate creation of such a layer offers a substantial gain in the strength of the part, though under prolonged variable (cyclic) loading it is necessary to avoid surface layers in every case, for otherwise the fatigue strength is lowered. (c) The use of isothermal treatment of austenitic steels. The effect of this on the stress-strain curve is to smooth out the elastic-plastic transition portion and to commence the strain-hardening process earlier. Also, the impact value may be doubled, and it is possible that in certain cases the static strength of notched specimens may be raised. (d) The use of cold work-hardening. After work-hardening, a metal possesses a lower initial hardening and a higher yield point. As a result of the former, the notch-sensitivity of a notched specimen is lowered and, as a result of the latter, the notch-sensitivity is raised. Thus the combined effect will depend upon which of the two influences is decisive. The study of the rules governing such behaviour should be founded on the evaluation of the basic mechanical properties—yield-point, resistance to shear, resistance to rupture, and the work-hardening property.

A further point stressed by Fridman is the vital necessity in many cases of paying attention to the reduction in area rather than the elongation of a specimen during a tensile test. In fact, he considers that one of the main problems in connection with testing methods is the construction of a reductometer which would measure the contraction of the diameter continuously right up to the moment of fracture.

By Dr. Ya. B. Fridman, All-Union Institute of Aviation Materials; Moscow, 1946; 228 pages, 20 roubles.

American Arc-Welding Patents

ALL who have taken steps to safeguard their interests in new ideas and inventions have been faced with what frequently is a stupendous task in making a thorough search of existing patents before determining the critical novel features upon which to establish a claim to any patent application they may make. There can be little doubt that in certain industrial fields a need exists for greater clarification of the patent situation and none more than in the welding industry with which this volume deals.

The material contained in this book, as the author points out, was collected over a period of about ten years in order to assist him in welding research and development work. As the work advanced, the material increased to such an extent that his colleagues persuaded him to have the work published in order to meet the welding industry's need for a patent reference book. The subject matter of this work is electric arc welding, and in case readers may regard the limits as narrow, it can be said that many gas welding material patents, especially on welding rods, alloys and also various gas welding applications apply to both processes; the latter are therefore included in this volume except those on equipment.

The book contains three main sections, the first giving a subject-matter index covering electrodes, welding rods and alloys, welding fluxes, chemical and metallurgical details concerning composition and application, electrode holders, welding shields, and welding accessories. The second section gives, in alphabetical order, a list of inventors and assignees and their inventions, patent numbers, and main subjects. Section three gives abstracts of patents in numerical order, with diagrammatic illustrations, filing dates, duration and names of inventors and assignees.

In a field such as welding, where the American industry plays a leading role, the American patent position almost represents that of the whole world and its investigation generally saves searches in other countries. A rough comparison of the patent positions in various countries on this subject shows the value attached by patentees all over the world to obtaining patent protection in the United States. The main reason for this is obviously the large American market, but it is also partly attributable to the fact that American patents are not subject to heavy taxes, compulsory licensing provisions or annual renewal fees to maintain the patent in force.

This volume covers a period of 63 years and the patents, numbering 1,250, are classified up to April 1, 1945. The majority of the patents summarised refer to the time when welding was established as a standard engineering process. This work not only serves as an invaluable reference to development in the welding industry, but it should, and doubtless will provide encouragement to patent research workers in other fields to publish their work more completely and in so doing assist in the exchange of ideas for the furtherance of research and the correlation of tasks. The compilation of this volume is the labour of many years and, as the edition is limited, the price seems relatively high. It should be borne in mind, however, that the preparation of this survey has necessitated research involving welding patents of 65 classes and 250 sub-classes, an undertaking too costly, if not impossible, for the average inventor or patent serviceman.

This volume provides an excellent survey of the patent literature relating to welding; it has an important historical significance and should be regarded as a work of reference on the subject especially for manufacturers and users of welding equipment and materials.

Compiled and edited by W. H. Simon, Ph.D., and published by Bailey Bros. & Swinfen, Ltd., 11, Ronalds Road, Highbury, London, N. 5. The size is 11 in. x 8½ in., 574 pages, and the price £10 10s. 0d.

Correspondence

Open Rotary Furnace

The Editor, METALLURGIA.

Sir,

In my letter, published in your August issue, I overlooked to refer to the "Ellipsoid Furnace," about which an article appeared in the July issue. This furnace, broadly speaking, can be considered as the forerunner of the "Open Rotary Furnace," although both furnaces have no connection whatsoever as regards their design or development.

The ellipsoid furnace is patented by Karl Schmidt Neckarsulm, a firm which has been frequently mentioned in recent reports by our experts sent to Germany to search for new development in industry. The furnace was built during the first World War and on exhibition soon afterwards. As Karl Schmidt became later subsidiary to the "Metallgesellschaft" Frankfurt a/M and this concern being intimately connected to the I.C.I., this new furnace should soon find an opening in Britain and in the U.S.A. for the melting of copper alloys, emanating from scrap and residues.

The melting drum of both furnaces have the same shape and, therefore, the same advantageous features, but handling mainly heavy base metals the ellipsoid furnace is built stronger. The great difference between these two furnaces is that the open rotary furnace is only slightly closed when melting, based on the fact of the different type of residues, and the ellipsoid furnace, after having been charged is tightly closed, to create the desired pressure within the furnace. Although having the same advantages it would not be advisable to use the ellipsoid furnace for the recovery of aluminium residues because of the intermittent melting and charging caused by the bulkiness of the aluminium residues.

As both types of furnaces are identical in their working it would have been more appropriate to have named the open rotary furnace the open ellipsoid furnace.

Yours faithfully,

H. O. LUEDTKE,
Metallurgical Engineer.

Holfast Road,
Sutton Coldfield,
Warwickshire.
September 7, 1946.

Dorman Long Developments

DORMAN LONG & Co., Ltd., Middlesbrough, are building at their Cleveland Works a new £500,000 power plant. Also at these works construction has begun of a new central ore unloading and ore preparation plant for the whole of the group at a cost of £1,250,000.

This latter scheme will also serve the Dorman Long £8,000,000 project for a new steelworks and universal beam mill on a virgin site between the Company's Cleveland and Redcar Works. A certain amount of preliminary preparation has already been put in hand on this project so that delay in starting can be reduced to a minimum.

It is anticipated that the new power plant will be in operation next February. Approximately 2,400 tons of steel will be used in the construction of the boiler plant itself and another 1,000 tons of structural steel framework in the power house building.

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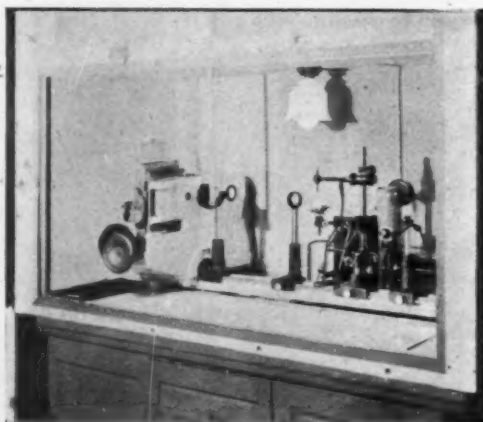
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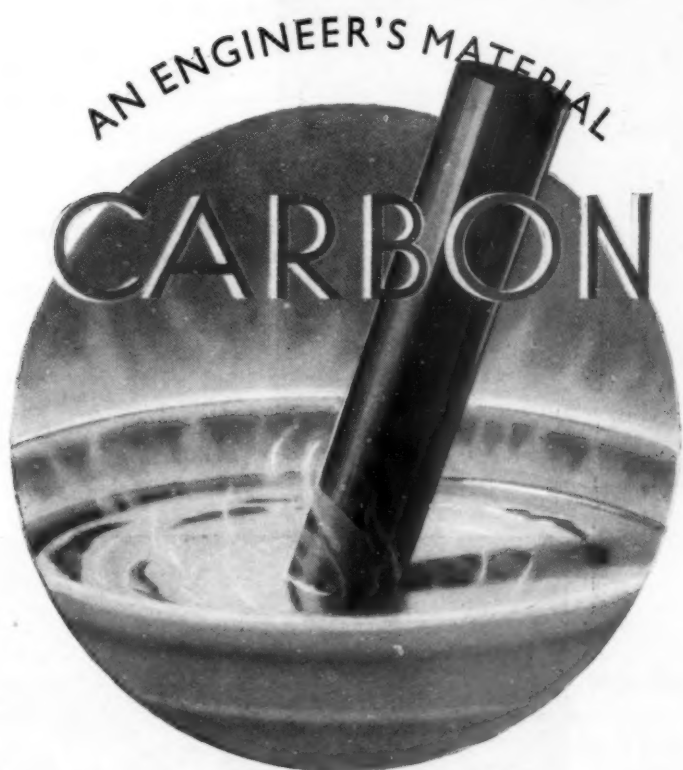
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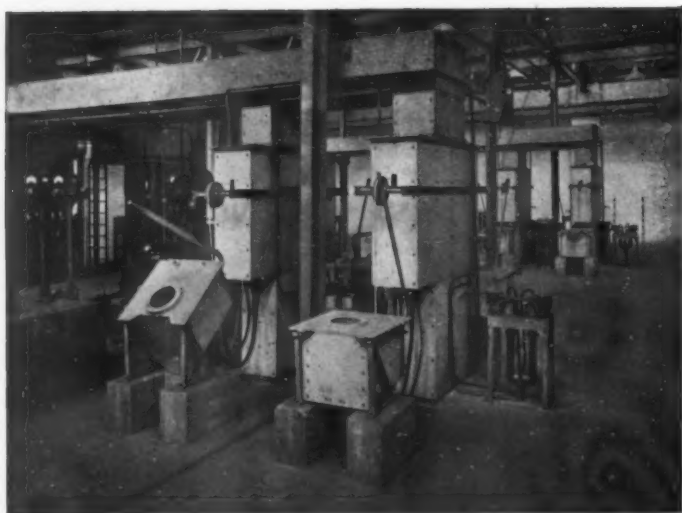
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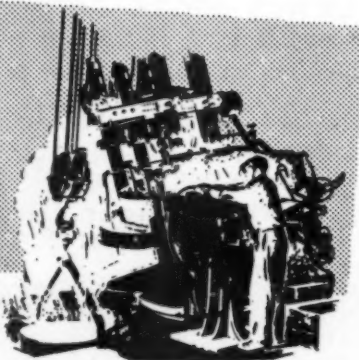


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Aside from specific use in making special grades of steels — such as manganese structural steels, manganese engineering steels, stainless steels, Hadfield steels, and tool steels — low-carbon ferro-alloys can also be valuable time-savers in the routine production of other grades of steel.


This illustration shows the first page of a new 8-page booklet, "Refined Ferromanganese Alloys for Steelmaking," which describes the advantages of "St. Lawrence" refined ferromanganese alloys in the production of quality low-carbon steels. The booklet also discusses the manganese and other special alloy steels in which these "St. Lawrence" alloys are a valuable aid to the steelmaker.

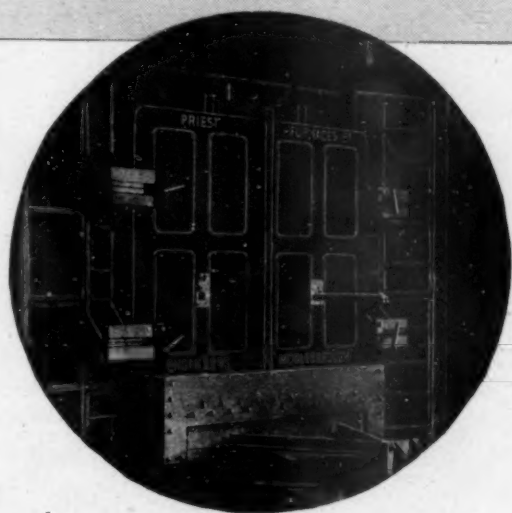
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● P. 35.

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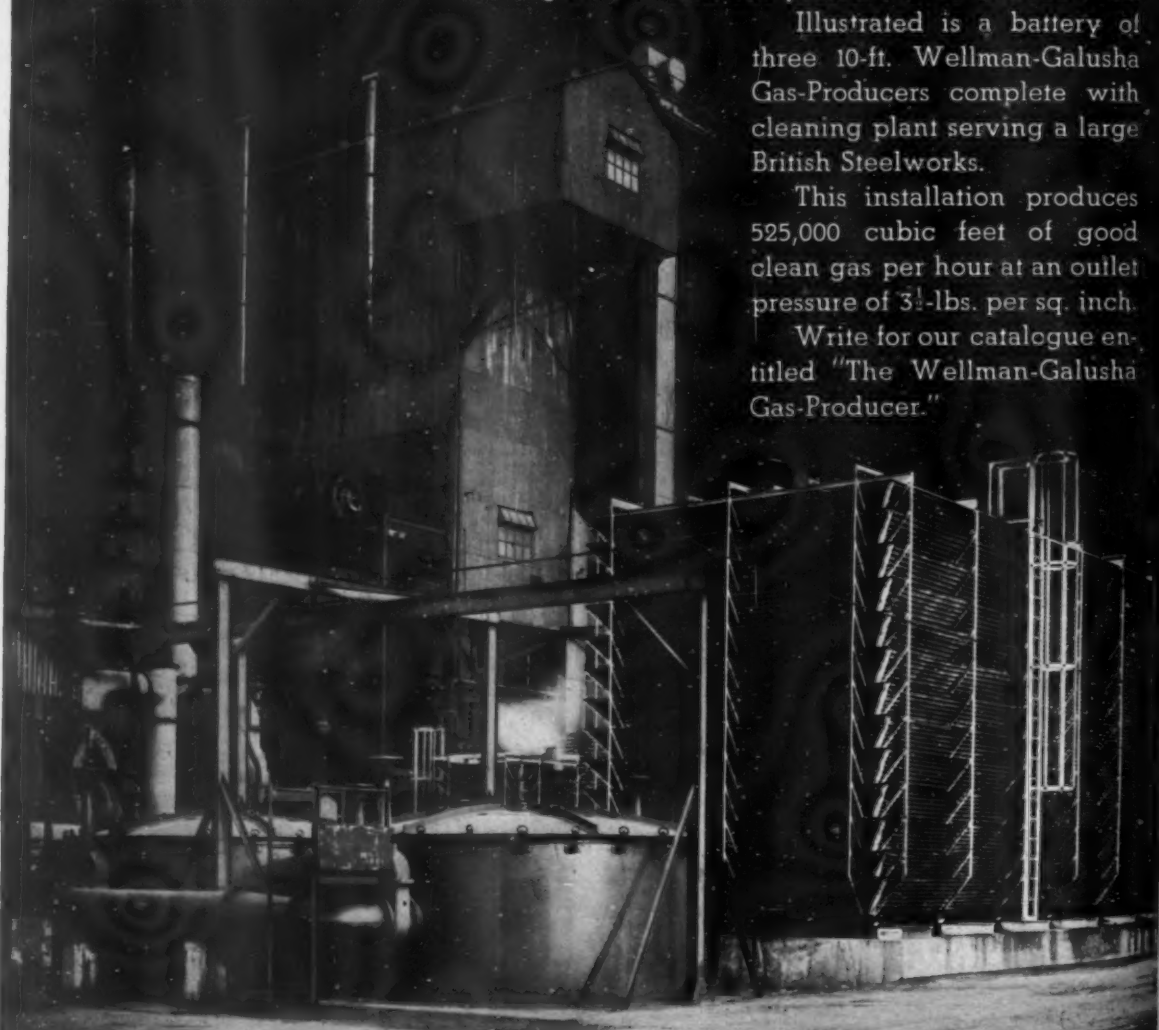
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Both in pure science and in its application to the arts, research is one of the most potent impulses to progress. Although primarily an individualistic activity, since new ideas, new designs, and new procedures in relation to the more efficient harnessing of the material world to the needs of mankind almost invariably originate with individuals, it is organised research that gives improvement in materials, machines, processes, and in understanding. In the following few articles brief reference is made to metallurgical research work of the National Physical Laboratory, and to various British research associations, which are definitely metallurgical or allied to metallurgy.

DURING the past few decades, and especially during the past few years, British industry has relied, to an increasing extent, upon the results obtained from research. The rare occasions when discoveries were made by happy accident belong largely to the past, to those times when there was little or no prior knowledge upon which to base experiments or ideas, but the inspiration or accident then formed the basis for continuous development. Even with the discovery of new alloys their development, as with existing alloys, generally begins in a very tentative manner, and is invariably preceded by extensive investigations which may, and frequently do, involve years of study before sufficient knowledge of a particular alloy is available to warrant a full-scale test. Even when a new alloy is put into service, it is the subject of continuous study, with a view to its improvement, particularly in the manufacturing technique employed. Thus, in addition to the progress of scientific discovery in the field of metallurgy, the perfecting of the practice of manufacture, forging, rolling or casting, expert manipulation with proper equipment, and the development of heat-treatment technique, are all essential to the successful development and application of both ferrous and non-ferrous metals and alloys.

Despite the advance of recent years, much remains to be done in determining how various engineering and metallurgical problems can best be solved, either by materials at present available or by improved types of materials. All the various branches of engineering present the metallurgist with problems. Thus, mining, electrical, textile, chemical, hydraulic, automobile, aeronautical, marine, and railway engineering and shipbuilding, as well as general engineering work, present problems for scientific consideration, and ceaseless study is necessary to meet the constant demands for better materials: materials which can be readily forged, welded or cast, and generally capable of easy manipulation and subsequent machining.

Research on metals and alloys is in a healthy state in this country, as will be noted from the following reports. Especially is this true so far as the approach from the fundamental atomic and physical side is concerned. The modern theory of atomic structure is the result of work in chemistry, physics and mathematics, extending over more than 150 years. Very great advances, however, have been made in the theory of the structure and properties of metals and alloys in

the last 25 years, arising largely from the discovery of the electron by Sir J. J. Thomson, which led to his and Lord Rutherford's brilliant studies on the atomic state and subsequently opened the way for the outstanding contributions by the late Sir William Bragg and his son, Sir Lawrence Bragg, who may be said to have initiated the first large-scale attack on the atomic structure of matter in the solid state. Valuable experimental studies in the crystal structures of alloy systems have since been made by many British investigators, and attention is particularly directed to a recent book by Hume-Rothery* whose work in this field is of a high order. The electron theory of metals involves a general background of atomic theory with which the metallurgist is unfamiliar; this book is intended to provide a bridge for research workers by which they may be led to an understanding of the ideas underlying the new theories.

In Britain research work of a fundamental and scientific nature is carried out by various research associations, in the research laboratories of Government departments or establishments, metal corporations, private firms or universities, by trained research staffs or individual workers. Applied research work is carried out in the works of interested firms or on a field scale under the auspices of practical research committees. An important feature of industrial progressiveness associated with the work done is the frankness and openness regarding results achieved. This is as it should be, provided necessary safeguards are ensured, so that the utmost development of a product may be achieved.

National scientific and industrial research is carried out under the auspices of the Department of Scientific and Industrial Research. This Department administers funds which are used for the maintenance of certain national research establishments and in making grants to 20 or more industrial research associations. Metallurgical research on a national basis is carried out in the Metallurgy Department of the National Physical Laboratory. A considerable amount of metallurgical research is also carried out in the Research Departments of Government factories, such as at Woolwich, and the Royal Aircraft Establishments.

Whilst large private firms and metal corporations will continue to develop and use their own laboratories,

* *Atomic Theory for Students of Metallurgy*, by William Hume-Rothery, M.A., D.Sc., F.R.S., 1946. Published by the Institute of Metals, 4, Grosvenor Gardens, London, S.W. 1. Price 7s. 6d. post free.

there is increasing need for co-operative research through research associations, such as the recently-formed British Iron and Steel Research Association, and other organisations which have operated successfully for many years, such as the British Non-Ferrous Metals Research Association, the British Cast Iron Research Association, and such allied associations as the British Refractories Research Association, the Welding Research Council, and various Coal and Coke Research Associations which provide facilities for the smaller firms, and permit both fundamental and applied research to be carried out for the benefit of members of the particular association. Industrial problems encountered by a member-firm which cannot be overcome by its own more limited equipment and staff may be referred to its association for investigation. The association is composed of an ordinary and trade membership, representing both large and small firms engaged in the particular industry. Apart from the Iron and Steel Research Association, the members of which are members

of the British Iron and Steel Federation, the organisation and method of working the other associations are similar.

The researches carried out or in progress by these metallurgical associations have, in the main, one or the other of the following objectives: (1) Prevention of troubles arising in melting or casting; (2) improvements in methods of working; (3) production of materials with special properties for particular purposes; (4) improvements in resistance of materials to corrosion and to oxidation at high temperatures; (5) effect of alloy additions; improvements of methods of testing, examination and analysis. These associations have done and are doing essential work in raising the standard of attainment in the industries they cover, and those that are concerned with non-ferrous metals and cast-iron research, for instance, are invaluable to the small firms which obviously cannot afford to employ research personnel of sufficient attainments or in sufficient numbers to cope adequately with conditions arising during these times of active scientific development.

Metallurgical Research at the National Physical Laboratory

By N. P. Allen, M.Met., D.Sc.

Superintendent of the Metallurgy Division

Progress has been so great during comparatively recent years that there are now few who question the indirect value of research, but there are still many who have the opinion that there is only a remote connection between research and industry. In the progress of metals and alloys the Metallurgy Division of the National Physical Laboratory has made contributions of a high order and, as will be noted from this report, work is proceeding on an increasing scale.

THE Metallurgy Division of the National Physical Laboratory provides a service whereby *ad hoc* metallurgical problems may be investigated on behalf of private concerns or Departments of State on a confidential basis, studies wider questions, mostly of a fundamental nature, of general interest to the metallurgical and engineering industries as a whole, and interests itself continuously, often with the co-operation of other Divisions of the Laboratory, in the development of the scientific tools that the metallurgist needs for the prosecution of his labours.

Of the first kind of activity, little specific can be said, but it occupies a considerable proportion of the energies of the Division, and supplies that contact with the outside world which the scientific investigator might otherwise miss. Cases of failure in service are handled together by the Engineering and Metallurgy Divisions, for the possibility of unsuitable design always exists, and it is perhaps a tribute to the work of the metallurgist that the fault is more often traced to the manner in which the material has been used than to any defect in its quality. Not all investigations in this class, however, have to do with failures. Frequently the objective is to find the best material for a given type of service or to overcome some manufacturing difficulty. Over a period of years it has been common for the Laboratory to be consulted with regard to metallic appliances used in surgery. An interesting investigation was recently completed of the attack of alloys by sera representative

of fluids in the body, and the possible use of light alloys in artificial limbs has also received attention. Another investigation of this kind, not strictly metallurgical but nevertheless of interest to those concerned with dusty operations, is the examination of industrial dusts for the presence of the mineral constituents which are responsible for silicosis. The Laboratory also advises the Home Office on the regulations governing the use of compressed gases in cylinders and other containers, and for many years has maintained a watch over the deterioration of gas cylinders in service. Stress corrosion phenomena occur on the inside surfaces of these cylinders in a sporadic way, and may at times result in potentially dangerous conditions. The elucidation of the combination of circumstances which gives rise to this attack has been tedious, but it is now fairly clear that the essential causes are high stress, condensates of moisture within the cylinder and the presence in the gas of specific impurities, of which sulphuretted hydrogen is perhaps the most important.

It is not unnatural that the longer range fundamental work should at present be coloured by war-time experiences. During the war the Division became deeply involved in problems relating to the quality of armour, and in the development of the armour piercing projectiles which played so important a part in tank warfare. The necessity for conserving alloying elements caused questions to be asked about the real influence of these elements in the steel, which could not always be

answered, and it came to be realised that information on this subject, though voluminous, is not as complete nor as systematic as it might be. As a result, the National Physical Laboratory has undertaken to co-operate with the Alloy Steels Research Committee (now part of the British Iron and Steel Research Association) in a systematic investigation of the influence of alloying elements in iron and steel. In part this is a continuation of work that the National Physical Laboratory was doing before the war, since for many years the determination of the equilibrium diagrams of alloys of iron, made with materials of the highest attainable purity, was an important feature of the Division's activities. This type of work will be maintained, but in addition greater interest will be taken in the mechanism of transformations from stable to unstable states, and in the detailed examination of the mechanical properties of phases containing alloying elements in solid solution. Much has been written in recent years suggesting that the mechanical properties of alloy steels are governed preponderantly by the microstructure as influenced by the hardening procedure and hardenability of the steel and there is no question that great importance must be attached to this structure; but when notched bar impact values of steel are considered, and all those obscure and complex attributes that are contained in the idea of "toughness," there remains a feeling that not everything can be explained in terms of the microstructure, and that important qualities reside in the ferritic matrix of the steel. Consequently, an examination is to be made of effect of alloying elements upon the mechanical properties of pure ferrite, giving special attention to that quality of resisting the formation and propagation of a crack which is thought to be so important in connection with welded structures. For this purpose appreciable quantities of extremely pure alloys will be needed, and arrangements have been made to install a large vacuum melting furnace by means of which, making use of a very high grade Swedish iron which has become available, it is hoped to prepare adequate quantities of alloys containing not more than 0.01% of any undesired impurity.

The investigations carried out between 1922 and 1939 on the determination of gaseous and non-metallic constituents of steel found many practical applications during the war and a valuable new technique, involving the examination by X-rays of the residues obtained by alcoholic iodine extraction, has been developed. In favourable cases it is now possible to report, with a great measure of confidence, not only the total oxygen content of a steel, but also its state of combination, and the way appears to be open for approaching the problems which the Ingots Committee of the Iron and Steel Institute had in mind when the Oxygen Sub-Committee was formed. The systematic examination of the products which arise when deoxidants are added to molten oxygen bearing iron is in hand, and this will be a preliminary to the study of the chemical equilibria established in the melt at high temperatures.

Weld metal has provided a very fruitful subject of study by this technique, and for the first time an understanding of its real nature is becoming available. Its investigation was commenced at the suggestion of the Department of Tank Design, who were interested in the relation between the composition of the weld rod coating and the hydrogen content of the weld in connection with the cracking of welded armour, and is now being pursued on behalf of the British Welding Research Association.

Researches on the minute impurities in alloys with high melting points make special demands upon the refractory materials employed. The manufacture of articles in sintered pure refractory oxides, such as alumina and beryllia, has reached a very useful level of perfection in the Laboratory, and makes an important contribution to the standard of the experimental work. Zircon has lately received attention on account of its good resistance to attack by slags, and sintered alumina on account of the good mechanical strength it can develop. The strength of sintered alumina, however, depends to a very marked degree on the details of preparation, the influence of which is being studied both at Teddington, and in an investigation carried out under a D.S.I.R. contract at the University of Leeds.

Of recent years work on magnesium alloys has been mainly concerned with the development of strong sheet alloys, the potentialities of the magnesium-aluminium alloys containing 4-10% of aluminium having been explored in some detail. They are naturally more difficult to roll than softer alloys, but good sheet with very satisfactory properties can be produced, and the ability of these sheets to be welded, and to resist various conditions of stress which might be encountered in service is being examined. Tests of weldability are arranged in co-operation with the British Welding Research Association and British Non-Ferrous Metals Research Association, who take a special interest in this subject. In addition, investigations of the constitution of magnesium zirconium alloys, and of the metallographic nature of the influence of cerium on the high temperature strength of magnesium are in hand.

If the advances in the metallurgy of uranium and kindred elements be excepted, there is little doubt that the outstanding metallurgical development of recent years has been in creep resistant alloys. The feverish activity of the war years was due to the necessity of finding materials suitable for jet engines, and the National Physical Laboratory, which has for many years carried out extensive researches on creep-resistant alloys for steam plant, played a useful part by carrying out the tests by which the merits of competing materials were assessed, and developing means of testing the fatigue resistance of alloys at high temperatures, which at certain stages assumed a critical importance. The contribution of the Engineering Division of the Laboratory in this connection was of special value. It is not too much to say that it was mainly the improvement in creep-resisting alloys that made the modern jet engine possible, and the preservation of our lead in this field will depend largely on effective progress in metallurgical research being maintained. At present, alloys based on the face-centred cubic iron-nickel-chromium alloys hold the field, and it will be many years before their potentialities have been fully exploited in all the types of power plant to which they can be applied. The improvements of thermal efficiency made possible by the use of very high temperatures in gas turbines is, however, such that already working temperatures beyond those likely to be within the scope of the austenitic iron-nickel-chromium alloys are being contemplated, and the use of refractory metals of very high melting point must be considered. Under these circumstances it has been thought desirable to gather information on the properties of the refractory metals, and at the same time to study as fully as possible the general means by which the creep resistance of metals and alloys may be improved. Those who have had most experience in this field most

readily admit that too little is known about the factors involved, and a better understanding cannot fail to reduce the amount of blind experimentation that will be required.

One line of attack on the problem is the examination by X-rays of the changes taking place in a metal while it is creeping under load at high temperatures, which have already been found to be significantly different from the changes which occur during rapid deformation. Much attention is being given to the use of X-rays in studying the elastic and plastic deformation of metals, and an investigation of the behaviour of a series of pure metals is being carried out. The investigation is planned to cover a range of rates of deformation and temperatures so as to provide a background against which the more complex phenomena that occur when alloying elements and impurities are present can in due time be viewed.

In the application of X-ray diffraction to metals, much is hoped from the recently developed use of the Geiger counter, which has the advantage of enabling a record to be obtained extremely rapidly, so that changes taking place in the sample can be followed more closely than heretofore. As a first application, a high temperature X-ray camera with Geiger counter recording has been constructed, with which it is hoped to be able to observe in detail the progress of phase transformations in alloys as they occur. Many other applications readily

suggest themselves. Progress in electronics is, indeed, placing an embarrassingly large number of new tools at the disposal of the research worker. The metallurgical applications of the electron microscope are being continuously studied, but the necessity for using in the microscope, not the actual etched surface of the metal, but an elaborately prepared replica of the surface, makes the technique difficult and introduces an element of uncertainty which can only be removed by repeated and painstaking tests. The electron diffraction camera is another instrument that awaits the full exploitation of its possibilities, and suitable problems are submitted to it as they arise. These spectacular instruments should not, however, be allowed to detract attention from important progress made in other directions. A feature of the chemical work of the Metallurgy Division has been the application of microchemical methods of analysis which quietly but continuously extend their scope and accuracy, and mention should be made of the development in the Physics Division of methods of determining the specific heat and thermal and electrical conductivity of metals at very high temperatures, which, though developed with the practical object of providing data required in calculating the heating and cooling times of large masses of steel, are capable, when systematically applied, of throwing new light on the physical behaviour of metals.

The British Iron and Steel Research Association

Director : Sir Charles Goodeve, O.B.E., D.Sc., F.R.S.

Although the Iron and Steel Research Association has only been functioning about a year its background of research in the industry is extensive. Research in this industry was initially organised in 1917, when five research committees were set up. Six years later a further effort was made to establish co-operative research on a wider basis by the formation of further committees. Two years later the Iron and Steel Industrial Research Council was formed and the new organisation took over last year. This report of the new organisation indicates the lines on which it is functioning in its support of the iron and steel industry and users of its products.

SINCE its formation twelve months ago, the British Iron and Steel Research Association has largely completed the task of building up its internal organisation and its staff of technical experts. A number of divisions, or panels, have been set up dealing with Iron Making, Steel Making, Mechanical Working, Steel Casting, Plant Engineering and Metallurgy.

It is not proposed at this stage to centralise the research work of the Association in any one laboratory but rather to use all existing facilities, supplementing these where necessary by special groups or research stations specialising in certain fields.

Iron and steel works and their associated laboratories throughout the land, universities, technical colleges, research associations of other industries, the National Physical Laboratory and Government research organisations are co-operating in wide fields of investigation of fundamental importance to the continued raising of the efficiency of the industry and its products.

The position of the British Iron and Steel Research Association, as of many research organisations, is that

it lies between the universities and the industrial laboratories. As Sir Charles Goodeve said in a recent address, the Research Association is concerned primarily with background or objective research and with new techniques and processes of common interest. It will prefer to support fundamental research in the universities rather than do such work in its own laboratories. Also, it will expect the firms' own laboratories to carry technical developments through to the applied stage and to carry out works investigation. It is important that the present gap in time between the discovery of new scientific knowledge and its application should be reduced very considerably and it is one of the Association's aims to see that this is done. The Association's excursions into the applied field will be mainly on problems of wide application.

As to what research stations of its own the Association may have, it is at the moment too early to say anything definite, except that these will be provided as the need arises. At the present time the Association has its own Corrosion Testing Station, with trial grounds in many

parts of the country. A Steel Coatings Research Station in Swansea has been set up and is getting under way, where both fundamental and applied research work connected with "pickling," cleaning, scaling, tinning and galvanising, vitreous enamelling, phosphate treatment and other associated steel problems will be undertaken. Close consideration is also being given to setting up a Metal Flow Research Station jointly with the makers of equipment for working metals. As the problems of metal flow are common to all metals, it is hoped that this station will also serve the non-ferrous metal industries.

An important aspect of the Association's work demanding continuous attention is to ensure that the brains of everybody connected with the industry are applied to the benefit of the whole industry as well as to that of a particular firm. Of equal importance is co-operation between the Association, the suppliers of equipment and raw materials to the industry, the users of the products of the industry and labour.

In order to present a slightly more detailed picture of the kind of work which each of the divisions of the Research Association is undertaking, it is convenient to summarise this briefly under divisional headings.

Iron Making Division

The work of this division has the ultimate aim of reducing the cost of pig iron by economy of fuel, increase in output and reduction of periods of abnormal working of the furnace. The attention of the division, so far, has largely been focused on the future of blast furnace research work and in this connection a second experimental blast furnace at Stoke-on-Trent has been completed and will start working soon. By this means it is hoped to add to present knowledge of what takes place inside a blast furnace and by means of a considerably higher degree of scientific control over the operation of a blast furnace, it will be possible to facilitate the study of the effect of varying conditions of distribution of materials at the stock line. In addition, experimental furnace research is being extended through explorations into the operation of full scale production furnaces. Parallel with these investigations, laboratory work at the Imperial College of Science and Technology is being vigorously pursued.

The Practice Committee, constituted of practical blast-furnace men, studies problems arising in the actual operation of a blast furnace. This Committee also has under consideration the possibility of standardising blast furnace equipment, such as tuyeres, coolers, etc.

Plans for full scale investigations on the improvement of sinter quality have been prepared and arrangements are going ahead for trials on one of the plants at Corby.

Steel Making Division

The Steel Making Division's programme includes over 20 research projects of great importance to the industry, to be carried out at steel works, universities, technical colleges and laboratories throughout the country. At the top of the list is an investigation of open hearth furnaces in order to determine how to design and operate the furnaces most efficiently. An experimental furnace at Stoke-on-Trent recently completed a series of tests and much useful information on the design and operation of this type of furnace has been obtained.

In addition to the work at the experimental furnace the efficiency of operation of production furnaces is being investigated. This largely depends on the installation

of instruments on production furnaces and is not yet complete, but a scheme of closer furnace control initiated by one management, has already led to increased output of the order of 20 per cent. and has emphasised the value of instruments.

Among the other matters being investigated by this Division are the factors influencing sulphur removal during steel making, slag chemistry and further items involving the "Physical Chemistry" of steel making. Also the Division is now responsible for the large programme of work carried out by the former Heterogeneity of Steel Ingots Committee of the Iron and Steel Institute, now reconstituted as the Ingots Committee of the Steel-making Division. This work includes a study of ingot surface defects and matters affecting the design and life of ingot moulds.

Close liaison with refractories research is being maintained through the B.R.R.A. and the Refractories Section of the B.I.S.R.A. The Division also organises periodic Conferences of Steel Plant Managers where problems of common interest are discussed. One of these Conferences is to be held at the beginning of October.

Mechanical Working Division

One of the important aspects of steel research is that of the manipulation of the steel ingot to convert the output of the steel furnace into shapes and sections required by the user. The Mechanical Working Division has been set up to study all the processes in use at present for the deformation of steel and to consider new ways of deforming or shaping steel to the needs of industry.

An already considerable programme of experimental research on the problems of rolling is in progress. On the fundamental side a number of investigations are in progress at the Cavendish Laboratory, where special apparatus has been developed for determining the compressive strength of materials for various rates of deformation and at various temperatures. The behaviour of single metal crystals when subjected to force is also being investigated as the fundamental processes of deformation are more easily observed in this way. The effects and efficiency of different lubricants at these pressures is being studied, also the phenomenon of creep.

Considerable progress has been made with researches at Sheffield where large scale experiments are carried out. A small experimental strip mill has been equipped for the investigation of cold rolling problems and apparatus has been developed for determining the high pressures between the rolls during cold rolling and the characteristics and performance of roll neck bearings.

The present programme also aims at experimental confirmation of existing theories of rolling, investigation of the effect of speed in rolling and a general study of the effect of back and front tension on roll force, power consumption and so forth.

An investigation of the drawing process is also in progress. A full bibliography and critical survey of drawing literature is being made and an experimental investigation is in progress on the effect of temperature above and below atmospheric on the drawing operation and the metallurgical properties of the wire produced.

The problems of metallic and other coatings on iron and steel are also being considered. An extensive programme of research has been drawn up and will be carried out at the new research station at Swansea mentioned above.

Plant Engineering Division

In order generally to improve the overall efficiency of operation and particularly that of the handling of materials in steel works, a special study is being made of layout drawings of representative Iron and Steel works both in this country and abroad. The design of steel works' buildings is also being studied and consultants will examine the principles involved and prepare design standards of typical structures. A subject of common interest to the Plant Engineering and Steel Making divisions is the layout of Melting Shops, and a conference will be held during October at which a series of papers on this subject will be presented by representatives of the industry. A standard specification for heavy cranes in Steel Works is being compiled and the performance of Steel Works locomotives and rolling stock is being studied. A contribution on the latter will be presented at the forthcoming conference of the Ministry of Fuel and Power.

The efficient use of fuel is a problem of the highest priority in the work of this Division and the Fuel Committee has put forward a comprehensive programme of research from which a short list of items will be selected for immediate study. Other investigations now in progress include the possibility of applying gas turbines for the provision of blast and power in Steel Works, and formal application has been made for the transference of a large gas turbine blower from the Hermann Goering Works to this country for investigation. A study is also being made of possible gas turbine schemes as part of a broad review of the relative merits of various sources of power, including high pressure steam and electricity.

Steel Castings Division

This division is concerned with improving the quality and scope of application of steel castings, and for this purpose has committees actively engaged in studying the melting of steel for castings, the metallurgical control in the foundry and the practical significance of the various distinctive properties required from Steel Castings. The current programme also includes the development of new techniques of value to the steel foundry industry, as well as ways and means of using substitute materials for certain materials in short supply, such as linseed oil and bentonite.

Metallurgy Division

The organisation of this division has now reached a stage where the committees dealing with its main lines of investigation have been set up. It will take over by the end of the year the work of the Joint Committees of the British Iron and Steel Research Association and the Iron and Steel Institute on Alloy Steels and Corrosion, which are now being administered by the Institute.

The Alloy Steels Committee is studying the influence of alloying elements on the properties of iron of high purity, with particular reference to hardenability. Work on overheating of steel and the effect of furnace atmospheres and an investigation on supersonic methods of testing have reached an advanced stage. Study of the influence of hydrogen in causing hairline cracks has continued and work is progressing on the technical problems of preventing hairline crack formation.

The Corrosion Committee has continued its work and has made progress in identifying the organisms responsible for the fouling of ships. It is carrying out full scale trials of corrosion and fouling resistant protective systems. Work at Cambridge has included investigations on corrosion fatigue and the development of cementiferous paints and paint which can be applied on wet surfaces.

The new Methods of Analysis Committee is considering a research programme continuing and extending the work of a number of previously existing committees which includes chemical, physical-chemical and spectrographic methods.

The remaining new committees on Metal Physics and New Techniques will begin active work shortly.

Conclusion

The purpose underlying the British Iron and Steel Research Association's work is clearly defined by Sir Charles Goodeve in the following brief statement of aims:—

"We must have in this country better qualities of steel at equal or less cost than anywhere else in the world and we must be first to introduce new steels and new processes, just as we are generally the first to discover them."

British Cast-Iron Research Association Features of Recent Work

By J. G. Pearce, M.Sc.

DURING 1946 the British Cast Iron Research Association has completed various investigations undertaken in connection with the war effort, and has been able to revert to its normal programme. One such investigation has recently been published.¹

Although equipment has been increased, it has not been possible to commence necessary building extensions, and the available accommodation for the existing staff is strained. The Council has in contemplation various ways of dealing with the situation. The basis of the internal organisation remains the same. The Intelligence Department is concerned with the Library, publications and public relations. In addition to the non-confidential *Bulletin*, which has now been issued for many years, and contains Foundry Abstracts

in six issues per annum, since July, 1945, confidential research reports have been issued to members in the *Journal of Research and Development*, and 17 papers have been published to date, while a beginning has also been made on presentation of the summarised results of earlier work in the form of foundry data, which will form the basis of a suitable book in due course. The Development Department deals with the day-to-day problems of the industry and applications in practice of discoveries made in the Research Department, which pursues a programme approved by the Research Committee. Each of these departments is in charge of a major committee of Council, although the Research Committee in addition, has a number of specialised sub-committees, including the one for each branch of

the industry. The Building Uses Department furnishes information for architects, surveyors and others interested in the application of cast iron to architecture and building. The author lectured to the Royal Society of Arts on Cast Iron in Contemporary Building and Engineering. The Scottish Laboratory takes care of the special interests of members in the north.

The problem of graphite formation continues to cover a group of activities which have been pursued, except for the war period, for a number of years. The work is pursued in the conviction that the control of the form, size and distribution of graphite will give the ironfounder the most potent weapon he could have for governing the properties of the product. Such control can only come from an understanding of the mechanism of the process, which covers the formation of graphite during solidification, as in the manufacture of grey iron, and the formation of graphite from the solid state during annealing, as in the manufacture of malleable cast iron. An allied problem deals with the mechanism of decarburising, as in the white-heart malleable process, and all these are being investigated.

The work has been approached through various channels, one of which has been the study of inclusions in cast iron. The first section of this was published in 1941.² A paper has been recently published by the Iron and Steel Institute from the same author, H. Morrogh, on "The Neutralisation of Sulphur in Cast Iron by Various Alloying Elements,"³ which was the result of an investigation of inclusions in alloyed cast irons, to complete the earlier work on the unalloyed irons. The later work confirms the earlier in that the only solid inclusions of importance in the alloyed irons are the sulphides. In addition, the reactions between sulphur and various alloying elements provide points of considerable interest. In view of the commercial

use of tellurium in ironfounding, another paper is now due for publication on the forms in which tellurium exists in cast iron. This work has necessitated attention to special analytical methods, and the photo-electric absorptiometer and spectrochemical apparatus are now being used for the analysis of elements present in both normal and very small amounts.

On the high-duty cast irons it is anticipated that the Institution of Mechanical Engineers will issue a report on the Acicular Cast Irons. A report has been issued by the Iron and Steel Institute on the impact test giving a suitable shock test using an Izod machine for cast iron.⁴ Work in conjunction with the British Iron and Steel Research Association continues on ingot mould material.

In addition to the above, special investigations are in progress for the various sections of the industry through the appropriate sub-committees of the Research Committee on Engineering Castings, Malleable Castings, White and Chilled Castings and Light castings.

During the year the Joint Committee on Sand Testing has prepared and issued methods of testing prepared foundry sands which represent agreed recommended methods by the bodies concerned.⁵

Members of the staff have participated in the work of the foundry teams which have visited Germany, reports on which will be available in due course, and have also visited the U.S.A.

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The British Non-Ferrous Metals Research Association

A Year's Progress

By W. L. Hall, B.Sc., A.R.S.M., B.N.F.M.R.A. *Liaison Department*

A GENERAL account of the research programme of the British Non-Ferrous Metals Research Association was given in the September, 1945, issue of this Journal. The twelve months that have passed since that review was written have seen a considerable measure of re-organisation and expansion in the Association's activities, changes indicative of a determination that the services provided shall be adequate to the demands likely to be made in the immediate future by the important section of British industry which it serves.

Research Board and Industrial Research Committees

Important changes have been made in the Committee structure of the Association during recent months, involving the appointment of a Research Board to replace the Main Research Committee which has hitherto been responsible, under the Council, for surveying and guiding the general course of the Association's research

work carried out under the Director. The Research Board has further appointed four Industrial Research Committees, covering the four main divisions of the non-ferrous metal industry:—

Aluminium, Magnesium and their Alloys.

Copper, Nickel and their Alloys.

Lead, Tin and their Alloys.

Zinc and Galvanising.

These Industrial Research Committees are representative of the particular section of industry concerned and are responsible for formulating a research programme appropriate to that section and for presenting to the Research Board annually a list of the researches they would like carried out. By the appointment of these Industrial Research Committees it is hoped that the research programme of the Association will maintain even closer contact than formerly with the most urgent industrial needs. For the guidance of each particular research project, Sub-Committees will continue to be

appointed, usually by the Industrial Research Committee concerned. For researches of general interest to the non-ferrous metal industry as a whole such as, for example, work on metallurgical applications of the spectrograph, the Research Sub-Committee will be directly responsible to the Research Board.

Expansion of Laboratories

Except for a small proportion of extramural work, all the research and other activities of the B.N.F.M.R.A. are once more concentrated at the Laboratories in Euston Street, London, the last section of the research staff having returned last month from the temporary war-time quarters at Berkhamstead, Hertfordshire. The staff has increased from 83 in June, 1945, to a present total of 116 and to provide the increased accommodation now necessary further buildings at the Euston Street site are being occupied. Use of this additional accommodation will eventually increase the available floor space by some 75 to 100% and will permit reallocation of space to existing work which in some departments is extremely congested as well as a substantial increase in over-all activities. Additionally, it is hoped that the serious damage suffered by part of the laboratories during the war may soon be remedied. The Association has now a membership of over 350 companies engaged in the production, manufacture and use of non-ferrous metals and a total annual income of about £55,000. To cover the increased activity of the Association which it is felt will be essential in the future, it is hoped to treble the 1945 industrial income. With the addition of the grant from the Department of Scientific and Industrial Research this should give a total annual income of £100,000.

The figure for the total staff already mentioned includes some forty trained scientific staff as well as the necessary complement of laboratory assistants, workshop and clerical staffs. Incidentally, it may be of interest to note here a feature of some junior staff appointments made during 1945. With the object of assisting in the supply of adequately trained scientists for industrial appointments, a grade known as "Bursars" has been created. Young men having recently graduated in metallurgy, chemistry, physics or engineering are appointed for two years to the Association's research staff in this grade for training in research methods. At the end of this period they will be available for positions in industry. Members of the Association have taken active interest in this scheme and have indicated that facilities for gaining industrial experience will be granted to the bursars during the time they are on the Association's staff. Some nine appointments as bursars have so far been made.

Library and Liaison

The return of the Information Department and Library to London during the year under review has of course been of great benefit to the research staff working at the Euston Street Laboratories, but the increasing use which is made of the services of this department does not come only from the Association's staff. A feature of the work of the Library during the war was the very heavy demand for loans of technical literature by members of the Association, Government organisations and others, and this demand has in fact increased since the end of hostilities. The issue of the monthly Bulletin, in which all the important published work of interest to the industry is brought to the notice of members, as

well as information regarding the release of the Association's confidential research reports, are among the responsibilities of this Department. In connection with the preparation of these Bulletins, over two hundred journals are received regularly by the Library.

The Staff of the Liaison Department (formerly called the Development Department) have been able to resume to a limited extent the practice of visiting members of the Association for the purpose of discussing the Association's work in general and in relation to the problems of any particular member. The major activity of the Liaison Department, however, continues to be concerned with the handling of confidential enquiries from members and Government Departments on technical problems connected with their work. To deal with such enquiries, which at present are being received at a rate of some 800 each year, the Liaison Department is able to call on the invaluable assistance of the Research and Information Departments where necessary. The subjects of these technical enquiries cover a very wide field. Some can be answered quickly on the basis of available information whilst for others a certain amount of experimental work may have to be carried out before a report can be made. Wherever the nature of the enquiry makes such a course desirable, visits are made to members' works to discuss practical problems on the spot. It may be of interest to mention here that Mr. W. C. F. Hessenberg (Chief Officer of the Liaison Department) went to America three months ago to fill temporarily the post of Co-ordinating Officer to the British Scientific Office in Washington. During his visit, many useful contacts have been made in Government and industrial circles in the U.S.A. This appointment has now almost terminated and Mr. Hessenberg will shortly be returning to this country.

Researches in Progress

Since the last review of the Association's research work appeared in this journal, many of the major researches have continued on the lines described at that time, and in order to avoid unnecessary repetition the reader is referred to the previous article so as to get a general picture of the research activities of the Association. Attention is, however, directed in what follows to some important additions to the research programme and to the publication of some papers dealing with important sections of the work. In addition to these published papers about thirty confidential research reports have been made available to members in the period under review.

MELTING AND CASTING

New work has been initiated to study in detail the solidification process in casting, particularly as regards the problem of temperature distribution and heat transfer in the solidifying metal. This work, which is at present only in the preliminary stages, is regarded as of great importance and will yield valuable information on the control of foundry operations with many metals.

Some work on the hot tearing characteristics of aluminium alloys has been published, in which a close relationship is indicated between the quantity of eutectic present in a solidifying alloy and the tendency to form hot tears.¹

CORROSION

Certain copper-nickel-iron alloys of low nickel content were developed by the Association during the war to

¹ D. C. G. Lees, *J. Inst. Metals*, 1946, **72**, 343.

provide materials resistant to corrosion by rapidly moving aerated sea water and at the same time capable of being fabricated by ordinary coppersmithing methods. These alloys are designed for use in parts of marine condenser systems, other than condenser tubes, where corrosion troubles have occurred when unalloyed copper has been used. Although for security reasons information was for a time restricted, full details have now been made available to members of the Association in the form of the usual confidential research reports. Patent protection has recently been granted to the Association in respect of the alloys concerned.²

A description has been published of apparatus constructed in the Association's laboratories for carrying out electro-chemical measurements in connection with corrosion studies.³ This equipment is at present being used in connection with an investigation of the reversal of polarity between zinc and iron which has been found to occur in hot water containing oxygen. It is thought that this phenomenon has an important bearing on the behaviour of galvanised steel tanks and cylinders used for hot water storage in domestic plumbing systems.

Some years ago, the corrosion of copper pipes as used for domestic plumbing was studied and information was obtained on some of the factors affecting cuprosolvency. Owing to other claims on the time of the Research Department, this work was suspended during the war but has now been resumed. Attention is being paid to the problems arising from a pitting type of corrosion which has been found to occur when copper pipes are used in certain areas.

The influence of biological factors in corrosion has long been recognised and in previous work carried out by the Association a method was developed for control of sulphate-reducing bacteria, one group of organisms which may give rise to corrosive influences. The method of control involves the use of certain dyestuffs and practical experience has now been gained with the method on a commercial scale. An account of some large-scale results has been published.⁴

JOINTING OF METALS

Research work on the welding of light alloys is carried out in close collaboration with the British Welding Research Association. Current work includes an examination of the fusion welding characteristics of high strength aluminium alloys and an investigation of certain problems associated with the welding of some wrought magnesium-base alloys. Patent protection has been obtained for a range of alloys of the aluminium-silicon-copper type with useful welding properties.⁵ These alloys are of medium strength but possess excellent welding characteristics in that the properties of the cast structure of the weld metal differ only slightly from those of the wrought basis material. The alloys are of the heat-treatable type but the response to heat treatment is relatively sluggish and the properties obtained in the heat-treated condition are not therefore altered to any marked degree by the heat of welding. A limited amount of work has also been carried out with quite encouraging results on the suitability of these alloys for pressing and anodising. The Association's interest in pressure welding, i.e., welding by application of heat and pressure without fusion, was mentioned in the

review which appeared in these columns a year ago. Some important results of this investigation have now been published and give an account of the pressure welding characteristics of various aluminium alloys in sheet form and some indications of the welding conditions necessary for each alloy.⁶ The investigator responsible for this work has had the opportunity of visiting Germany to study the conditions under which the process was operated in that country. An account of work on the pressure welding of aluminium alloy bars is shortly to be published.

Under the guidance of a Research Sub-Committee of the B.N.F.M.R.A., work has commenced on the investigation of some metallurgical problems affecting the wider use of aluminium bronze electrodes and filler rods for welding aluminium bronze and other copper base alloys in both cast and wrought form.

Although most of the Association's effort during the war years in the field of soldering was directed to the solution of practical problems arising out of the enforced use of solders of low tin content, a certain amount of more fundamental work was at the same time carried out. The results of an investigation of some aspects of capillary flow in the soldering process have been published recently.⁷ Current work is directed to a study of the fundamental aspects of the jointing process including brazing as well as soldering. Work is in progress with a view to elucidating the fundamental mechanism underlying the wetting of solid by liquid metals.

MECHANICAL PROPERTIES

The mechanical properties of lead and lead alloys, in particular creep and fatigue properties, are of great interest to both cable makers and the manufacturers of lead pipe and sheet. The B.N.F.M.R.A. has carried out important investigations on this subject in the past but during the war work on lead was restricted to certain special problems mentioned below. Research has, however, now been resumed on a substantial scale and a series of lead alloys are being examined under creep and fatigue conditions. The part played by the Association in the development of the L-Delay fuse was publicly announced some time ago. This device depends for its action on deformation leading to fracture of a lead wire under controlled conditions. It is obvious that in its development a considerable amount of information on the creep properties of lead alloys was required and the Association was well placed to assist in the matter in view of its previous investigations in this field. Dr. J. McKeown, of the Association's staff, is named as one of the joint inventors in the British Patent Specification which covers the essential features of the L-Delay.⁸

Full details of the Association's work in connection with the metallurgical factors connected with L-Delay have been made known to members in a confidential research report.

The investigation of the mechanical properties of aluminium alloys at elevated temperatures on behalf of the Ministry of Supply continues.

OTHER RESEARCHES

An electron microscope is being obtained for the Physics Section. When this instrument is delivered it is proposed to start a thorough investigation of its possible uses in metallurgical research.

² British Patent Specifications 577,063 and 578,283.

³ P. T. Gilbert, *J. Sci. Instruments*, 1945, **22**, 235.

⁴ T. Howard Rogers, *J. Soc. Chem. Ind.*, 1945, **64**, 292.

⁵ British Patent Specification 575,589.

⁶ R. F. Tylecote, *Trans. Inst. Welding*, 1945, **8**, 163.

⁷ A. Latin, *J. Inst. Metals*, 1945, **72**, 265.

⁸ British Patent Specification 572,541.

In the field of spectrographic analysis it has been shown in the Association's laboratories that the reproducibility of results depends upon the characteristics of the discharge circuits. A study of the characteristics of various types of discharge circuits was made by means of a cathode ray oscillograph and other methods as a result of which a general purpose source unit has been constructed. This unit is capable of providing a whole series of excitation conditions intermediate between those prevailing in the conventional spark and arc, and experiments so far carried out on the analysis of a number of alloys show that a much higher accuracy is obtainable with this type of source than when using a simple condensed spark.⁹ Further developments along these lines are pending, including a comparison of the behaviour of the B.N.F. source unit with that of a commercial unit of American manufacture which is also designed to provide a wide range of excitation conditions.

Some considerable space was devoted in last year's review to the Association's investigations into the aluminium-magnesium alloys. These have covered such subjects as the development of porosity in casting due to reaction between the metal and moisture in the mould, the development of blistering on welding and the tendency of alloys of higher magnesium content to fail by stress corrosion in certain environments after certain heat treatments. Directly connected with the first two subjects, a fundamental investigation of the reaction of these alloys with water vapour and of the absorption of hydrogen was carried out, and the results published.¹⁰

Some time ago information was released to members on research work on certain aspects of the oxidation and scaling characteristics of copper base alloys at elevated temperatures. The main results have been published.¹¹

Another wartime activity of the Association led to the development of an interesting method for the generation of hydrogen based essentially upon the reaction between finely powdered magnesium and sea water. Patent protection has been granted to the Association in respect of this method.¹²

⁹ A. Walsh, *B.N.F.M.R.A. Bulletin*, 201, March, 1946, pp. 60-80.

¹⁰ R. Eborall and C. E. Ransley, *J. Inst. Metals*, 1945, **71**, 525.

¹¹ A. P. C. Hallows and E. Voce, *Metallurgia*, June, July, 1946, **34**, 95-109, 119-122.

¹² British Patent Specification 579,246.

Although, as stated, this review does not claim to be a full account of the Association's activities in general or of the research programme in particular, it is hoped that enough has been said to indicate the broad field covered by the work. The many points on which this work directly connects with current industrial needs will be readily apparent, as will also the Association's realisation of the need for ready adaptability to meet any new demands which may be made by industry.

Recent Papers and Publications by the British Non-Ferrous Metals Research Association

"Hot Tearing Tendency of Aluminium Casting Alloys," D. C. G. Lees, *J. Inst. Metals*, 1946, **72**, 343.

"Electrochemical Measurements in Corrosion Studies," P. T. Gilbert, *J. Sci. Instruments*, 1945, **22**, 235.

"Inhibition of Sulphate-Reducing Bacteria by Dye-stuffs. II. Practical Applications in Cable Storage Tanks and Gas Holders," T. H. Rogers, *J. Soc. Chem. Ind.*, 1945, **64**, 292.

"Pressure Welding of Light Alloys Without Fusion," R. F. Tylecote, *Trans. Inst. Welding*, 1945, **8**, 163.

"Capillary Flow in the Soldering Process and Some Measurements of the Penetration Coefficients of Soft Solders," A. Latin, *J. Inst. Metals*, 1946, **72**, 265.

"A General-Purpose Source Unit for the Spectrographic Analysis of Metals and Alloys," A. Walsh, *B.N.F.M.R.A. Bulletin*, 201, March, 1946, pp. 60-80.

"Reaction of an Aluminium-Magnesium Alloy with Water Vapour, and the Absorption of Hydrogen," R. Eborall and C. E. Ransley, *J. Inst. Metals*, 1945, **71**, 525.

"Attack of Various Atmospheres on Copper and Some Copper Alloys at Elevated Temperatures," A. P. C. Hallows and E. Voce, *Metallurgia*, June, 1946, **34**, 95.

"Attack of Various Superheated Steam Atmospheres Upon Aluminium Bronze Alloys," A. P. C. Hallows and E. Voce, *Metallurgia*, July, 1946, **34**, 119.

British Patent Specifications: 572,541; 575,589; 577,065; 578,283.

[These papers have all been referred to in this article (see footnotes); they are collected here for convenience.]

The British Refractories Research Association

By A. T. Green, O.B.E., F.R.I.C., F.Inst.P., M.I.Chem.E.

Director, British Refractories Research Association

Research on refractories is of great importance to the metal manufacturing industries and very valuable work has been carried out in recent years, especially in dealing with the iron and steel industries. In his report last year, Mr. Green directed particular attention to advances made in blast-furnace refractories; another important feature of research has been selected upon which attention is focussed in the present report—basic refractories for use in open-hearth furnace roofs.

IN previous reviews of the work of the British Refractories Research Association published in this series, a policy has been adopted of selecting a feature of research on refractories that has been prominent during the previous year, and outlining the advances made in that field. It is felt that this treatment is better suited to the scope of a short article than an attempt to review progress in all branches of the Association's work. It may be recalled that last year, attention

was focussed on blast-furnace refractories: this year it is intended to deal more especially with basic refractories of the special type needed for use in open-hearth furnace roofs.

The output of a steel furnace is a function of many factors, some metallurgical, some operational, others connected with furnace design. One of the most important operational factors which influences output is the temperature of working, and the upper limit, clearly, is

controlled by the properties of the refractory used in the construction of the furnace. The problem is not new; it confronted Sir William Siemens almost a century ago, and was then solved by the production of a new type of refractory, viz., the lime-bonded silica brick. The outstanding behaviour of this type of brick when subjected to compressive forces at high temperatures has enabled the open-hearth furnace to be operated at tapping temperatures in the region of 1,650°–1,670° C. It must not be forgotten, however, that Siemens first used the silica brick for building furnaces worked by the acid process; when the basic process was introduced, the continued use of acid refractories in the roof and side-walls must have been undertaken with apprehension. As we now know, however, the action of iron oxide on silica is slight so long as the conditions remain oxidising, while lime and silica remain immiscible provided that alkalis and alumina are absent. The success of the acid silica bricks in contact with basic slagging oxides can therefore be understood, but the use of such bricks nevertheless imposes a definite upper limit to the temperature at which the steel furnace can be worked.

An alternative material is magnesite, but normal magnesite bricks may spall, and when used in steel furnace roofs even electrically-fused magnesite bricks have not given effective service. Chrome bricks, on the other hand, have always suffered from weakness under-load at high temperatures. Attempts were therefore made in several countries to combine the merits of the two types of refractory in a composite chrome-magnesite product. This proved highly successful, and it was found that suitably graded mixtures of chrome ore and magnesite gave bricks of high refractoriness-under-load and high spalling resistance. Rarely, however, is success in research achieved fully and completely at once. In the case of the development of chrome-magnesite refractories a new source of trouble was their growth and bursting in contact with hot ferruginous slags; then again, certain types of chrome ore were observed to yield friable bricks; different raw materials too were found to give products varying widely in their properties.

Each of these problems has received careful study. It became evident in 1939, as the prospect of war grew certain, that Great Britain would be faced with a serious shortage in the supply of basic refractory raw materials. The problem was discussed in general terms by the Open Hearth Refractories Joint Panel, and in 1941 a sub-committee was appointed to examine all problems associated with the use of basic refractories in steelworks. A study was first made of the properties of available raw materials, and it soon became clear that the problem required treatment from two aspects. There was the immediate need to utilise raw materials from untried sources, but, in addition, there was the long term need for understanding the fundamental causes of the observed differences in the behaviour of these materials. The Basic Bricks Sub-Committee was so constituted that each aspect could be studied; manufacturers of basic refractories and steelmakers were both represented, and the Research Association provided the essential link for co-ordinating the work and providing the fundamental background. During the past five years the work of this Sub-Committee has gone steadily forward, and it is felt that the general quality of basic refractories has been well maintained under difficult conditions.

As already hinted, however, the main task was to

study chrome ores and magnesites fundamentally. On account of their greater complexity chrome ores have received the closer attention, and the earlier investigations were devoted mainly to the study of the causes of the bursting of chrome-magnesite bricks in contact with ferruginous slags. It was first necessary to study a testing procedure that would allow the atmosphere to be controlled during the test. This would enable on the one hand the iron oxide slag to be of a definite composition, while on the other hand pure ferrous spinels could be used without fear of oxidation taking place on heating. By melting pure ferrous oxide and mixtures of ferrous oxide and magnetite on the surface of chrome ore and spinel test-pieces, it was shown that magnetite must be present for bursting to occur. Even so, magnetite did not give rise to bursting with all materials: chromite and magnesiochromite gave the highest bursting expansion, hercynite and magnesia spinel gave lower expansions, and magnesioferrite and magnesite gave no bursting expansion at all. The magnitude of the bursting expansion, however, depended in part on the depth of penetration of the iron oxide slag. Nevertheless, it was possible to correlate the amount of expansion obtained using pure spinels with that obtained using chrome ores. Ores rich in chromic oxide, Rhodesian for example, gave higher bursting expansions than ores rich in alumina, such as the Grecian ore.

The test was later again modified so that volume expansions were obtained without melting one of the ingredients. The work was also extended to include many other spinels, so that the complete chemistry of spinel reactions could be covered. It was found possible, after many months of experiment, to make the following generalisations:—

(a) Chromites do not give volume expansions with any other chromites or alumina spinels, but do give expansions with ferrites, titanates and stannates. Chromite itself causes much bigger volume expansions than magnesiochromite, unless the second spinel in the mixture is a ferrous spinel.

(b) Alumina spinels give no expansile effect with other alumina or chrome spinels, but do cause expansion with some ferrites, titanates and stannates. Here again, hercynite gives larger volume expansions than magnesia spinel, unless the second spinel in the mixture is itself a ferrous spinel. The alumina spinels give rise to less volume expansion than do the corresponding mixtures containing the chrome spinels; for example, the ferrites, titanates and stannates cause much more expansion with chromite than with hercynite.

(c) Stannates, titanates and ferrites do not, in general, give any volume expansion when mixed with themselves or with each other; two exceptions, however, should be noted, namely, magnetite and ferrous titanate, and magnetite and magnesiotitanate.

Many attempts have been made to simulate volume expansions in binary mixtures of materials other than spinels that form solid solutions, but in no case has any expansion been obtained. It would seem, therefore, that these expansion phenomena are peculiar to spinels. This being the case, some explanation of the effect may be found in the characteristics of the spinel crystal lattice. All spinels belong to the cubic system, but some fifteen years ago T. F. W. Barth and E. Posnjak, working in America, demonstrated that there are two spinel structures; these differ in the manner of distribution of the metal atoms in the spinel lattice. It has been shown by

the B.R.R.A. that the more important spinels that constitute chrome ores belong to one type, whereas the ferrites generally and, by analogy, magnetite have the second type of spinel structure. Experiments have shown that volume expansions take place only when spinels of different types enter into solid solution. The magnitude of the expansion would seem to depend on the relative ease with which one form of a spinel changes to a second form under the influence of another spinel. It has been shown experimentally that with mixtures of magnetite and chromite, magnesiochromite or hercynite, the maximum expansion occurs with mixtures containing about 80% of magnetite; this indicates that it is the magnetite which undergoes the transformation. There is also some indication that the magnitude of the expansion is determined by the rate at which solid solution, and presumably transformation, takes place. The rate of solid solution might be expected to increase as the space lattice dimensions of the spinels approach each other more closely. If this is indeed the case, an explanation might be afforded of the fact that the chromites cause a larger bursting expansion with magnetite than do the alumina spinels.

Radio is Used to Direct Prospectors in the Urals

By ZINOVY YANTOVSKI

THE Central Research Organisation of the Urals Geological Administration, occupying four floors in a large building in the Urals' capital, Sverdlovsk, serves as the centre of operations for some 120 teams of prospectors working in the territory, and directs their activities and receives reports from them daily over a two-way radio system. Direct personal contact with these teams, when they are out in the maps' "white spots" is maintained by a special air unit which not only visits each party in turn, but ensures a regular distribution of mail and fresh supplies.

This Central Organisation, which played an important part during the war, has now intensified its efforts in order to open up the rich Urals area of hundreds of thousands of square miles, to intensive industrial exploitation.

Alexander Pronin, chief geologist of the Administration, told the writer of activities of this interesting organisation. He said: "The main task of the Administration consists of geological exploration, preliminary prospecting and general appraisal of mineral deposits from the point of view of industrial exploitation. A detailed exploration of discovered deposits is conducted by the geological departments of various ministries and their local bodies. Large prospecting groups of the Ministries of Ferrous and Non-Ferrous Metallurgy and of the Coal Industry work in the Urals under the control of our Administration.

"Our Administration has a number of permanent expeditions and many smaller prospecting parties. A special expedition studies Fay, the northern zone of the Urals. Composite expeditions conduct research in the north-western, southern and central Urals. Stationary geological prospecting parties are included in these expeditions.

"During the war the Urals geologists fulfilled an enormous task in uncovering new sources of raw materials for industries evacuated to the Urals. They discovered

Experiments have also shown that the magnitude of the bursting expansion is increased in the presence of small amounts of mineralisers. It would be expected that the presence of such materials would accelerate the rate at which solid solution occurs, and might also facilitate the rearrangement of the metal atoms in the spinel when transforming from one type to the other.

The development and the results of this investigation have been given here in some detail since they offer an excellent illustration of the value of long-term research to industry. The work is admittedly incomplete, in particular certain features of the mechanism of the volume expansion are still obscure; on the other hand, it is felt that definite progress has been made with the problem.

Research in other fields of interest to the metallurgist has also proceeded, notably the study of the spalling of magnesite bricks, a close investigation of the clay-quartz system, the behaviour of firebricks on reheating and the production of improved insulating refractories. The Mellor Laboratories, headquarters of the Research Association, are being extended to enable a still greater widening in the scope of the Association's activities.

extensive deposits of manganese, bauxites, rare metals and acid-resistant asbestos and opened up new coalfields. For the first time graphite has been found in the Urals. A new iron ore region in North Kazakhstan promises to become a second source of supply for the famous Magnitogorsk Iron and Steel Works.

"At the present time we are prospecting for iron ores, coal and fuel gases. A special party is searching in the Northern Urals for raw materials for a new metallurgical plant which will be constructed under the new Five-Year Plan.

"After the war geological expeditions received large quantities of additional material and are being technically re-equipped. The Government allotted a large number of automobiles, caterpillar tractors and mobile electric plants for boring machinery. Each party has mobile shops and laboratories.

"Scientific research is an important part of the Administration's work. Twenty parties and several expeditions are gathering data for a geological map of the Urals to a scale of one to 200,000. This colossal task is to be fulfilled in five years and will become the scientific foundation of further research. Hydrogeological and geo-morphological maps have been already compiled while a map of quaternary formations nears completion. A special expedition is studying the physical properties of the Urals. One of its tasks is the compilation of a large-scale magnetic map. Aero-magnetic survey is being made with the aid of aviation. The Administration has several thousand employees of whom 400 are engineers and technicians."

The population aids the geologists by taking an active part in their work, and spend free time prospecting. This trait is perhaps inherited from the historic ore-finders who discovered the treasures of the Urals some centuries ago and there is a special department of the Administration which examines the claims of the inhabitants whose rights are protected by the law. The Government has also announced special rewards for the first finds. Not long ago the Administration paid a large sum to Prokopi Mezdr, an old gold prospector who found manganese in the Northern Urals.

THE INSTITUTE OF METALS

Annual Autumn Meeting Held in London

This meeting marks the beginning of the Institute's return to normal peace-time activities and it was well attended by members, including many foreign members and visitors. The future policy of this Institute, as indicated in a recent report of a Committee on the subject, is to help all classes in the industry it embraces, and the Council are acting on the recommendations. Enthusiasm for a broader outlook on the possibilities of the Institute is growing and gradually the trend will be towards greater attention to applied research without sacrifice of fundamental work.

THE thirty-eighth annual autumn meeting of the above Institute was held at the Institution of Civil Engineers, London, S.W. 1, on September 10th and 11th, 1946, at which, in addition to the normal business meeting, two technical sessions were held. The Chair was taken by the President, Col. P. G. J. Gueterbock, C.B., D.S.O., M.C., T.D., M.A.

The President at the opening of the meeting extended a cordial welcome to all members present. Once again, he said, we welcome foreign members, and he referred particularly to the Honorary Corresponding Member to the Council from Switzerland, Dr. Zeepleder. This meeting marks the beginning of the Institute's return to normal peace-time activities. Unfortunately it was not possible to do all that was wished at this meeting, but progress is being made. Next year, continued the President, the Meetings Committee hope to arrange the normal dinner and dances at the annual meeting in London in March, and the Council have accepted the invitation of the Glasgow Section to hold the autumn meeting there in September.

The Council have acted as far as possible on the recommendations of the Committee on Future Policy, said the President, who believes that members can rest assured that the effect will be to improve the mechanism for the running of the Institute, and will help in the general extension of its services. The difficulty in carrying out the Committee's recommendations is largely a financial one. It is for the Council to consider the financial applications of any programme it is desired to carry out. This matter, however, is receiving attention and soon it is hoped to do more to interest the rank and file of the industry.

Mr. Vaughan Williams

The President referred with deep regret to the sudden death of Mr. Vaughan Williams, chief metallurgist of the General Electric Co., Ltd., Wembley, who was chairman and formerly honorary local secretary of the London Section. He did a great deal for that Section in other official capacities. On behalf of members he extended the Institute's sympathy to the widow and family.

National Certificates in Metallurgy

It is hoped to issue soon a report on the first year of operation of the scheme for National Certificates in Metallurgy. The scheme is going well, quite up to expectations and the Institute is continuing to co-operate very closely in other educational activities with the other metallurgical institutions. The President is of the opinion that this question of education is going to be of increased importance in the work of the Institute.

Monographs

Attention was directed to the recently published monograph by Dr. Hume-Rothery on "Atomic Theory," published at the low price of 7s. 6d., and distributed free to members who ask for it. Members interested in that branch of metallurgy should certainly avail themselves of a free copy. Another monograph is expected to be published shortly, viz., "An Introduction to the Electrical Theory of Metals," by Dr. Raynor.

Retirement and Nomination of Officers

The Secretary, Mr. K. Headlam-Morley, announced that the following Honorary Officers and Members of Council were due to retire at the annual general meeting in 1947, and, with the exception of the President, would not at that time be eligible for re-election in their present capacities:—

President: Col. P. G. J. Gueterbock, C.B., D.S.O., M.C., T.D., M.A.

Vice-President: G. L. Bailey, M.Sc.

Members of Council: Sir Clive Baillieu, K.B.E., C.M.G., O.B.E., M.A.; John Cartland, M.C., M.Sc.; A. G. C. Gwyer, B.Sc., Ph.D.; C. Sykes, D.Sc., Ph.D., F.R.S.

To fill the vacancies thus caused, the Council made the following nominations:—

President: Col. P. G. J. Gueterbock, C.B., D.S.O., M.C., T.D., M.A.

Vice-President: John Cartland, M.C., M.Sc.

Members of Council: Professor Leslie Aitchison, B.Sc., D.Met.; John Arnott; Dr. Maurice Cook; A. J. Murphy, M.Sc.

TECHNICAL SESSIONS

At the first technical session, held after the official business of the meeting, three papers were presented for discussion. At the session, held the following morning, two technical discussions were held simultaneously, in the Lecture Theatre and the South Reading Room respectively, five papers being presented at the former and four at the latter discussion. The papers presented are briefly summarised in the following notes.

ANTIMONIAL 70 : 30 BRASS

By D. McLEAN, B.Sc. and L. NORTHCOTT, D.Sc., Ph.D.

THE availability of brass scrap in the form of fired cartridge cases had raised the questions of (a) possible contamination of the metal when such scrap was used as part of the charge and (b) the effect of any impurities so introduced upon the properties and working behaviour of the brass. The principal impurity is known to be antimony, but small quantities of lead

and sulphur may also be present, and the work described in this paper concerns a study of the properties of three series of 70 : 30 brass alloys containing, respectively, antimony, antimony plus lead, and antimony plus sulphur.

The paper is divided into four parts. The first covers the examination of rolling behaviour and mechanical properties of 70 : 30 brass containing 0.0-2.2% antimony and 0.0-1.2% each of lead and sulphur. The second deals with physical tests performed on the plain antimonial series and with the constitution of the alloys with up to 2.3% of antimony. The third part is concerned with the elimination of the harmful effects of antimony by means of additions to the melt. In the final part the experimental results are discussed.

Discussing the results the authors state that the effect of a given amount of antimony on the mechanical properties of brass depends on three factors: heat-treatment, casting segregation, and zinc content. With homogeneous 70 : 30 brass, the chief precaution in practice, so far as heat-treatment is concerned, is to heat and cool rapidly through the dangerous range of temperature 200°-450° C. With 0.05% of antimony, uniformly distributed, air-cooling of single thin strips should be rapid enough, as the following results on 0.08-in.-thick bend specimens show:—

	Method of Cooling.		
	Water-Quenched	Air-Cooled	Furnace-Cooled
Number of reversals . . .	20.0	26.7	20.0
Percentage of water-quenched value . . .	100	92	60

The second factor, namely, the segregation present in chill-cast ingots, is sufficient to render chill-cast material more brittle than furnace-cooled material of the same antimony content, despite the more rapid cooling of the former. It is probable that, if antimonial brass ingots can be satisfactorily broken down without the aid of pre-annealing, the antimony content is low enough to cause no trouble in subsequent operations. Turning to the third factor, the influence of zinc content is such as to suggest a reversal of previous policy on the disposal of antimonial brass scrap. This has been to use antimonial scrap in 60 : 40 melts, but with such a high zinc content antimony is extremely harmful. It seems preferable to use the scrap in high-copper melts, where the antimony contents involved would be well within the solid-solubility range and much less harmful.

The mechanism of antimonial embrittlement is not quite clear. The grain-boundary character of the cracking occurring in, and the fracture of, embrittled material show that an abnormal grain-boundary condition is responsible for brittleness. The discontinuous precipitate clearly plays only a minor role. Although a grain-boundary-film appearance has been detected in embrittled material, it is not considered certain that an ordinary precipitation mechanism is at work. There is some doubt as to whether the film appearance is a true precipitate or some other condition which cannot always be revealed under the microscope, such as a narrow zone of transformed lattice, or a pre-precipitation phenomenon. To summarise the evidence: on the one hand, facts which fit in with a precipitation hypothesis are the shape of the solid-solubility curve, the effect of heat-treatment on mechanical properties, and microscopical evidence. On the other hand, doubt is raised about the nature of the film by the peculiarities of etching behaviour and

difficulty of detection described earlier, and also by the fact that the electrical-conductivity results do not show the increase in conductivity usually found when precipitation occurs. Despite this uncertainty, however, the assumption that the films are a brittle precipitate identical in nature with the discontinuous precipitate but for some reason infrequently detected, provides a working hypothesis, namely, that in specimens slowly cooled or tempered above about 250° C. the precipitate becomes more continuous and naturally has an embrittling effect in proportion to its continuity.

There is an interesting comparison between this grain-boundary effect in brass and temper-brittleness in steels, where slow cooling through, or heating in, a dangerous range of temperature produces embrittlement of a type shown by the notched-bar impact test, the tensile properties being unaffected, whereas rapid cooling causes no embrittlement. It is also of interest that the types of fracture in brass are similar to those in steel, namely, intercrystalline in the temper-brittle condition and transcrystalline in the non-temper-brittle condition. Further, a grain-boundary constituent has not been reliably detected in steel in the temper-brittle state. Similarity also exists with the embrittlement of copper by bismuth and possibly by selenium and tellurium.

The brittleness of antimonial brass in the cast state is probably due to the same mechanism as grain-boundary embrittlement in recrystallised material. The rounded blue particles are unlikely to cause much harm, owing to their rounded shape and fairly uniform distribution. Antimony is so highly segregated in cast brass that, with an average antimony content of 0.02%, the blue constituent could often be seen and, therefore, the maximum segregated content in solution must have been about 0.6%. In regions of such high antimony content the tendency to grain-boundary embrittlement must be very marked. Pre-annealing restores ductility by assisting homogenisation and thus reducing the number and intensity of such regions.

The fire-cracking which occurred in the earlier cold-rolled ingots is assumed to be due to (i) embrittlement on heating through the dangerous temperature range, intensified by casting segregation and cold work combined with (ii) the transverse-tensile surface stress resulting from the final cross-rolling pass. Slow heating might be more harmful than rapid heating. Thus, Price and Bailey,¹ during their work on the effect of bismuth in brass, found fire-cracking to occur after a light break-down and not to be entirely avoided by slow heating. In the discussion on their paper Smith² stated that "Castings (of 70 : 30 brass) rolled 30% reduction and then annealed at 600° C. always fire-cracked if they contained bismuth (0.009-1.0%), even though they were slowly heated with the furnace."

Conclusions

- (1) The divergent opinions held on the effect of antimony on brass can be largely accounted for by variations in heat-treatment, zinc content, and casting segregation.
- (2) The solid solubility of antimony in 70 : 30 brass decreases from 0.6% at 550° C. to about 0.01% at 200° C. The corresponding values for antimony in pure copper are 11 and 2%; thus, the solubility of antimony at 200° C. is reduced from 2 to 0.01% by 30% of zinc

¹ W. B. Price and B. W. Bailey *Trans. Amer. Inst. Min. Met. Eng.*, 1942, 147, 136.

² C. S. Smith, discussion on Ref. 32, *Trans. Amer. Inst. Min. Met. Eng.*, 1942, 147, 142.

and it is fairly certain that higher zinc contents cause a further reduction.

(3) Decreased solubility is accompanied by an increased tendency to grain-boundary embrittlement. The effect of antimony in unsegregated brass is, therefore, determined largely by heat-treatment and zinc content owing to the influence of these two factors on antimony solubility. Antimonial 70 : 30 brass is embrittled by furnace cooling or holding in the temperature range 200°-450° C.

(4) In cast brass the effect of antimony is intensified by the segregation in which this element is prone and a pre-annealing treatment improves ductility by assisting homogenisation. Under the conditions stated in the present work, 0.05% of antimony is about the maximum for satisfactory cold rolling of 70 : 30 brass ingots, but within the limit for hot rolling.

(5) A working hypothesis that accounts for the effect of antimony on mechanical properties is based on the assumption of a brittle intercrystalline precipitate. Embrittlement increases with the continuity of this intercrystalline precipitate and the continuity, in turn, depends on heat-treatment. The continuous form has not been consistently revealed under the microscope, although the discontinuous form can be regularly detected.

(6) Lead and sulphur both impair ductility and intensify somewhat the effect of antimony and, on the whole, antimony intensifies the effects of these elements.

(7) Antimonial embrittlement can be overcome by the addition of elements which form innocuous compounds with antimony. Phosphorus forms such a compound and eliminates antimonial embrittlement but slightly impairs hot-rolling behaviour. Lithium also forms a compound with antimony, improves hot- and cold-rolling behaviour, and eliminates antimonial embrittlement, but apparently only at the expense of a big reduction in general mechanical properties.

THE HOT-TEARING TENDENCIES OF ALUMINIUM CASTING ALLOYS

By D. C. G. LEES, M.A.

THE British Non-Ferrous Metals Research Association has conducted an investigation into the casting characteristics of aluminium alloys with a view to elucidating the factors responsible for the variations between alloy and alloy. Amongst the important properties of an alloy for foundry use is its susceptibility to showing "hot-tears," i.e., cracks in the finished casting when free contraction is restrained during cooling from the liquid state to the solid. The present paper describes tests devised to compare the hot-tearing behaviour of a variety of alloys under controlled conditions, discusses the factors responsible for tearing, and makes practical recommendations for its avoidance.

The commercial alloys tested, with their analyses, are given in Table I. Two tests were used, one in sand and the other in a chill mould. The test casting developed for use in sand moulds comprised four bars 11 in. long and of cross-section $\frac{3}{8} \times \frac{3}{8}$ in. These were poured from a common runner, and the contraction of the bars was restrained by bolts cast in the ends and passing through slots in the moulding box, the bolts being free to move with the contraction of the bar to varying amounts before the restraining nuts bore on the outer wall of the box. Thus, one bar was completely restrained (except for any slight "give" allowed by the elasticity of the

TABLE I.—COMPOSITION OF COMMERCIAL ALLOYS TESTED.

Alloy	R.S.I. or D.T.D. Specification No.	Analysis							
		Cu, %	Fe, %	Si, %	Mg, %	Ni, %	Mn, %	Ti, %	Others
Alpax ..	L 33	..	0.22	11.9	..	..	..	..	Na as modifier
Alpax γ ..	245	0.02	0.43	11.7	0.44	..	0.45	..	Pb 0.04
D.T.D. 424 ..	424	3.09	0.73	5.00	0.06	0.13	0.37	0.07	Sn 0.08
R.R. 50 ..	133B	1.67	1.13	2.35	0.11	0.97	..	0.17	..
R.R. 72B ..	131A	1.55	1.29	0.60	0.77	1.45	..	0.15	..
N.A. 226 ..	304	4.24	0.11	0.15	..	..	0.03	0.16	..
Aeral A ..	294	3.1	0.30	0.15	1.14	..	0.22	0.009	Cd 1.46
Ceralumin A ..	280	2.72	1.12	1.30	0.63	1.58	0.10	..	Cb 6.10
									Pb trace
									Sn 0.02
									Zn 0.08
									Zn 0.05
									Sn 0.02
Ceralumin B ..	287	1.54	0.99	2.24	0.06	1.41	0.05	..	..
Birmabright ..	165	..	0.31	0.16	5.56	..	0.41	0.005	..
N.A. 350 ..	300	Trace	0.07	0.06	10.9	..	0.03	Trace	..
7% Cu ..	L 11	6.6	0.20	0.24	..	..	..	0.09	..
11% Cu ..	L 8	11.2	0.20	0.12	..	..	..	0.12	..
Al-Cu-Zn ..	L 5	2.72	0.43	0.27	..	..	..	0.13	Zn 13.8
Y alloy ..	L 24	3.72	0.41	0.30	1.71	2.09	..	0.14	..
R.R. 53 ..	131A	2.14	0.93	1.93	1.36	1.10	..	0.06	..

box), the second could contract freely for one-tenth of its natural shrinkage, and so on. Tears tended to occur in the hotter parts of the bars near the ingates, and the alloys tested were classified according to the degree of restraint required to produce a tear.

The test casting made in metal moulds comprised a simple cylinder, which is cast vertically, with flanges at the upper and lower ends. Four different dies were used, giving shanks of $\frac{3}{8}$, 1, $1\frac{1}{2}$ and $1\frac{3}{4}$ in. dia.; the shank length, 5 in. with $\frac{1}{4}$ in. radius of fillet and flange dia. 2 in. The dies were used at 200° C. and the surfaces of the mould cavity were coated with acetylene soot. The pouring temperature was 720° C.

Results from these tests are reproduced in Table II.

TABLE II.—SUSCEPTIBILITY OF COMMERCIAL ALUMINIUM ALLOYS TO HOT-TEARING IN SAND Moulds AND IN COPPER DIES.

Alloy	Order of Susceptibility in Sand-Cast Tests	Order of Susceptibility in Copper Die Test	Eutectic Index
L 33	A	A'	0.97
Alpax γ ..	A	A'	0.94
D.T.D. 424 ..	A	B'	0.42
N.A. 350 ..	A	B'	0.30
Super-purity aluminium ..	A	B'	Very small
L 8 ..	A	C'	0.25
Birmabright ..	A	D'	0.13
Ceralumin A ..	A	D'	0.13
R.R. 53 ..	A	D'	0.12
L 11	A	E'	0.15
Ceralumin B ..	A	E'	0.13
Y alloy ..	A	E'	0.10
N.A. 226 ..	C	E'	0.09
Aeral A ..	B	E'	0.08
L 5 ..	B	E'	0.07
R.R. 72B ..	C	E'	0.03
99.7% Al	C	E'	Very small

Note.—The results of the hot-tearing tests are expressed in the following manner.

Results of Tests in Sand Moulds.
 A No tears under full restraint of contraction.
 B Tears under full restraint but not under 9/10 restraint.
 C Tears under 9/10 restraint but not under 8/10 restraint.
Results of Tests in Copper Dies.
 A' Does not tear in $\frac{3}{8}$ -in. dia. shank.
 B' Tears in $\frac{3}{8}$ -in. dia. shank, but not in 1-in. dia. shank.
 C' Tears in 1-in. dia. shank, but not in $1\frac{1}{2}$ -in. dia. shank.
 D' Tears in $1\frac{1}{2}$ -in. dia. shank, but not in $1\frac{3}{4}$ -in. dia. shank.
 E' Tears in $1\frac{3}{4}$ -in. dia. shank.

From a consideration of these results it will be seen that the tests in copper dies discriminate between several alloys which the sand-mould test had grouped

together as not prone to tearing. At the lower end of the list the copper-die test groups together a number of alloys which in the original test showed widely different behaviour. The two tests together adequately cover the whole range of alloys, since the copper-die test readily discriminates between alloys whose resistance to hot-tearing is high, and the test in sand moulds is suitable for alloys of lower resistance to tearing.

The present work was carried out almost entirely on degassed melts and, since it is well known in the die-casting industry that dissolved gases in the melt reduce the susceptibility to hot-tearing, a few experiments were made to find whether the tests would demonstrate this effect. A melt of 7% copper alloy (L 11) was taken and a 1-in. dia. test on the degassed melt gave a torn casting. This melt was then reheated, gassed by plunging a small piece of green wood for about 20 sec., and a further test made in the 1-in. dia. die. No tearing was observed in the casting. A pouring temperature of 700° C. was used each time, and reduced-pressure tests confirmed that gas was absent in the first test and present in the second.

Experiments have been made to compare the susceptibility to tearing of specimens of the same alloys having different grain-sizes. The results show that coarse-grained material is invariably more prone to tearing than fine-grained metal of the same composition, and as an example the following experiment may be quoted.

As a result of this investigation the author concludes that the most important factors determining the susceptibility of alloys to tearing are: (1) constitution, particularly eutectic content; (2) grain-size; and (3) gas content. The following practical recommendations are also given.

The probable tendency of an alloy to crack by hot-tearing in castings or to crack when welded under constraint can be assessed from the calculation of the amount of liquid which solidifies in a form characteristic of a eutectic. This is termed the eutectic index, and a method of calculating the figure is given in an Appendix. A large grain-size will also increase these tendencies, but the presence of dissolved gas in the metal will tend to neutralise hot-tearing. It is recommended that where complicated castings, particularly die-castings, are required, in which it is impossible to arrange directional solidification to give complete feeding and to avoid solidification contraction stresses, alloys should be chosen which contain considerable quantities of a phase which will solidify in a form characteristic of a eutectic. In aluminium alloys the presence of appreciable quantities of copper and/or silicon (particularly silicon) readily achieves this result. Control of grain-size, which should be as small as practicable, is also desirable, and where the necessary freedom from hot-tearing cannot conveniently be achieved by any other means some gas to be evolved during solidification may be introduced into the metal.

THE APPLICATION OF SOME THERMODYNAMICAL PRINCIPLES TO THE LIQUIDUS SURFACES OF ALLOYS OF ALUMINIUM WITH MAGNESIUM, SILICON AND IRON

By H. W. L. PHILLIPS, M.A.

DURING recent years several papers have been published in which some of the fundamental equations of thermodynamics have been applied to data derived from constitutional investigations on alloy

systems. Generally, the purpose has been to confirm or supplement experimental data, or to obtain information about the latent heat of fusion of certain phases. On reading these papers, one is struck by the possibility of making still wider applications of these principles. To mention but a few questions to which the answers might be obtained by this means: (1) Is it possible to calculate the co-ordinates of a ternary or quaternary liquidus surface from a few measurements at one temperature and a knowledge of the latent heat of fusion of the primary phase? (2) Is it possible to find the composition of an unidentified primary phase from the curvature of its liquidus isothermals? (3) Can the solidus curve of an alloy series be calculated from experimentally determined liquidus points and a knowledge of the latent heat? (4) Is it possible to ascertain whether a liquid phase contains its elements in the form of independent atoms, stable or transient associations, or undissociated intermetallic compounds? The investigation of the constitution of the aluminium-rich alloys with magnesium, silicon, and iron¹ which has involved the collection of data on three binary, three ternary, one quasi-ternary, and one quaternary system, seemed to afford a good opportunity of studying these possibilities.

As a result of this study the author is of the opinion that an answer can be given to the various questions. It appears, for instance, to be possible to determine the co-ordinates of a liquidus surface from a knowledge of the heat evolution and linear interpolation, provided that interpolation is not carried to low temperatures in the neighbourhood of a binary valley. This should reduce appreciably the amount of experimental work needed, besides serving as a check on experimental points. It is not possible to predict the composition of a precipitating phase from a graph of the liquidus isothermals. Such a graph may, at the most, be used as confirmatory evidence. Solidus curves cannot be calculated from experimentally determined liquidus points and a knowledge of the latent heat. It is possible to obtain qualitative information about the molecular species present in the liquid phase, and about the existence of associated groupings, but quantitative treatment is out of the question.

THE AGEING OF HIGH-PURITY ALUMINIUM ALLOY CONTAINING 4% OF COPPER

By MARIE L. V. GAYLER, D.Sc.

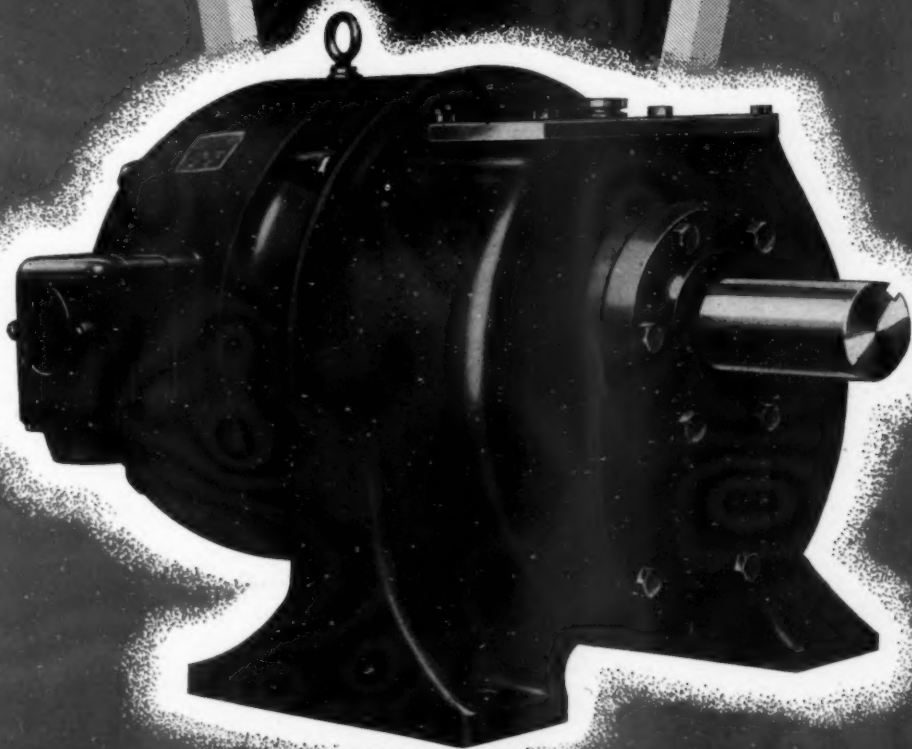
THIS paper embodies further experimental results on the ageing of high purity aluminium alloy containing 4% of copper, and forms part of a general research programme of the National Physical Laboratory. The results are based on microscopical examination and the Brinell hardness measurement of alloys in various stages of ageing.

The effect of rate of quenching on subsequent ageing at room temperature and at 130° C. has also been studied, and the data thus obtained has amplified our knowledge of the changes in structure taking place during ageing and of the mechanism of the ageing process.

Changes in microstructure which take place on ageing have been studied at room temperature and at 130° C. on specimens cooled at different rates from the solution

¹ H. W. L. Phillips, *J. Inst. Metals*, **72**, p. 151.

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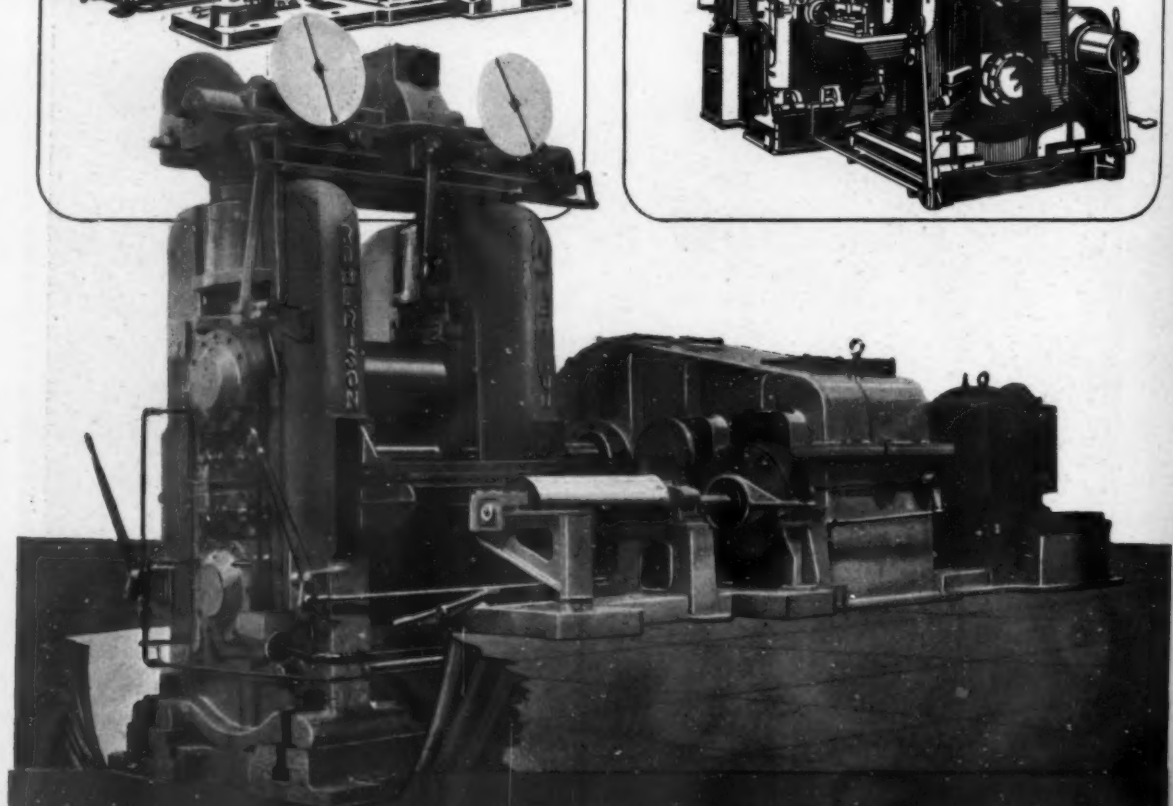
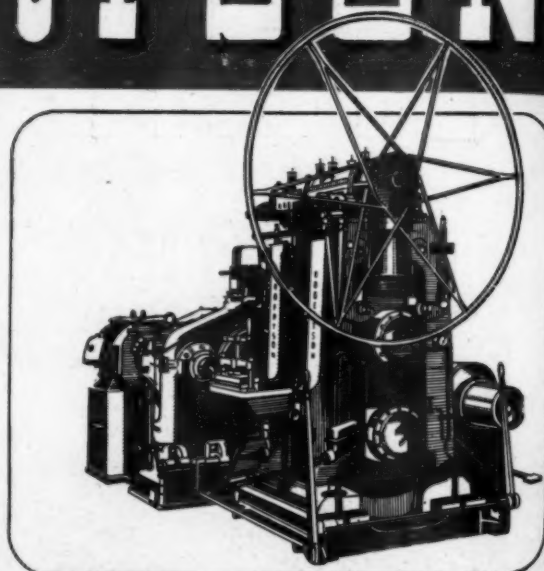
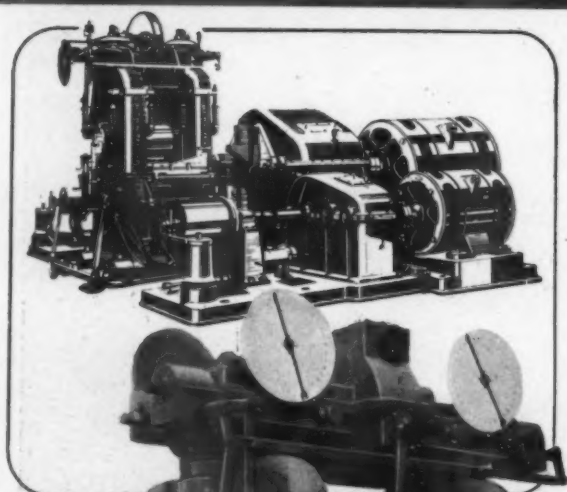
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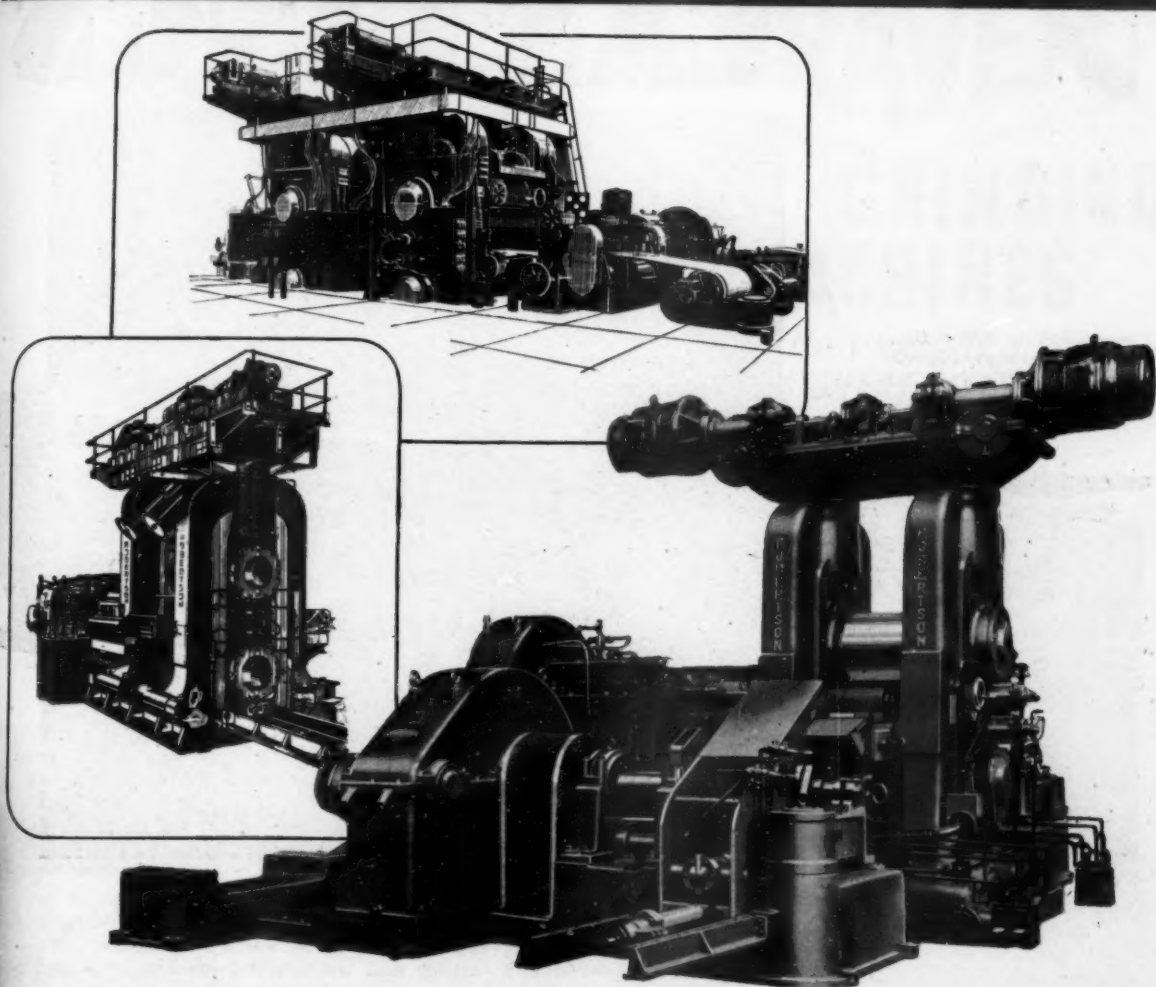


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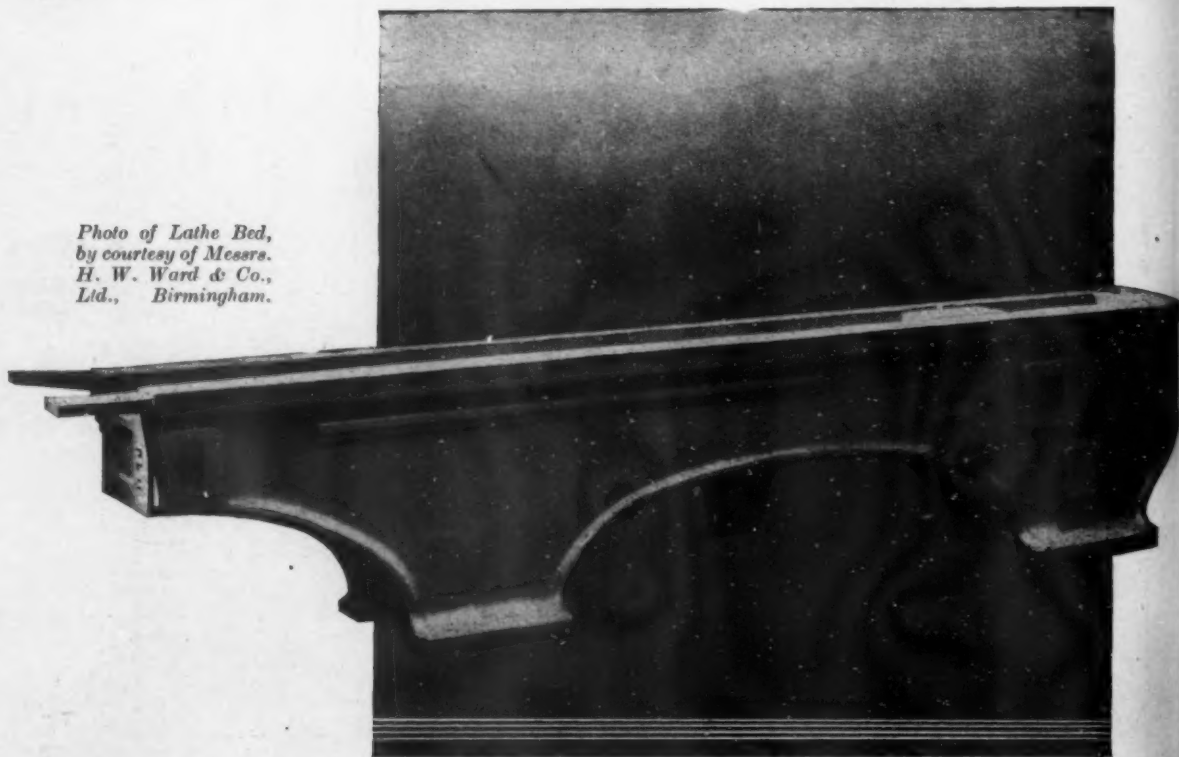
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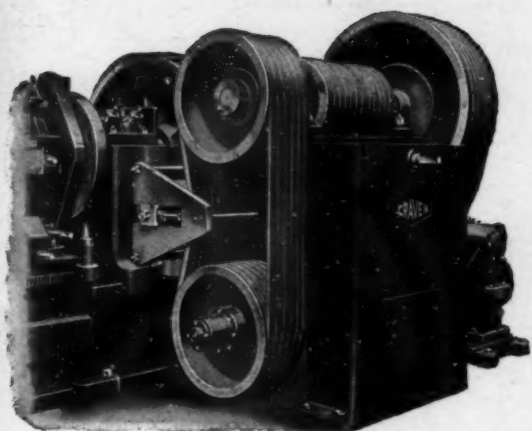
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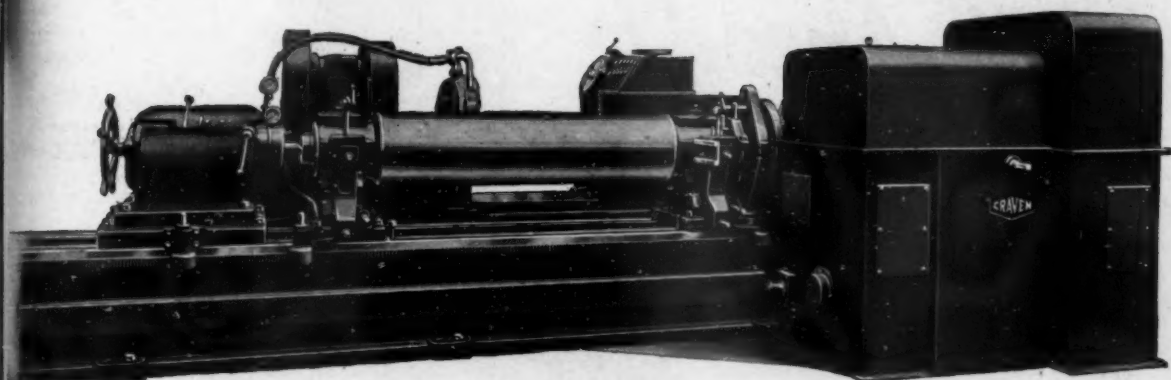
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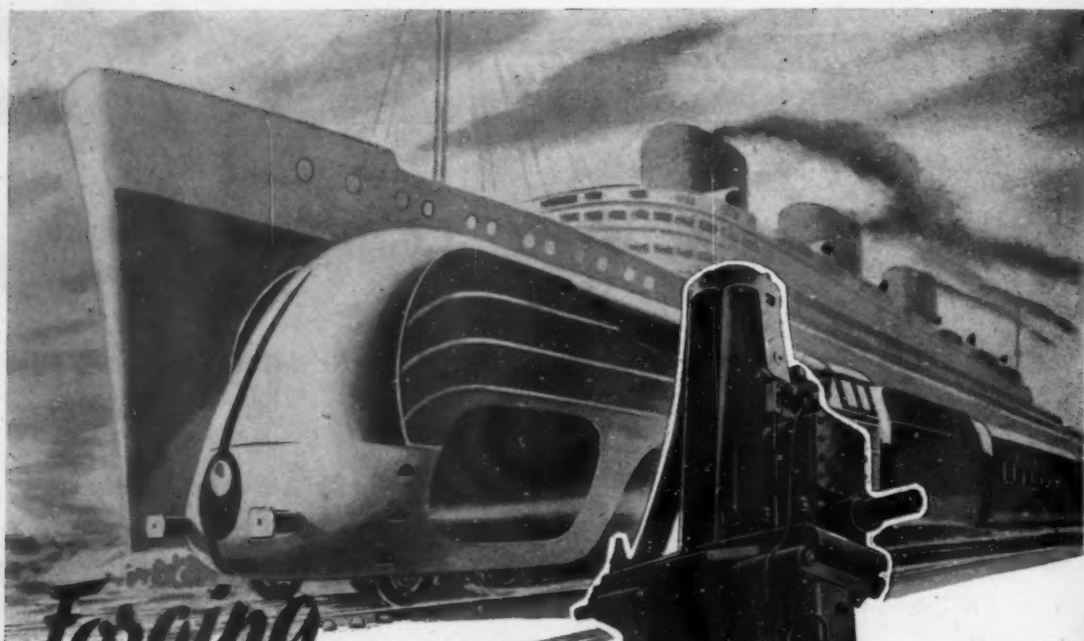
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heat-treatment temperature and correlated with the accompanying changes in Brinell hardness. It is shown that decreasing the rate of quenching has a pronounced effect on the subsequent ageing at room temperature; but at 130° C. the ageing curves differ from each other only in the early stages, i.e., up to about 8 hr. at 130° C.

The evidence obtained proves that the age-hardening of these alloys is due to the precipitation of copper or copper-rich particles and to the simultaneous formation of crystallites of the aluminium solid solution stable at the temperature of ageing, and not to the precipitation of either α - or β -CuAl₂. The principal points in the evidence are: (a) The first increase in hardness is due to the segregation of copper atoms to form plates on (100) planes. (b) The "flat" on time-hardness curves is associated with the formation of copper-rich aggregates of a critical size (depending on the ageing temperature), the precipitation of which relieves the strain-hardening set up in the surrounding matrix. Sub-microscopic particles of copper or of copper-rich aggregates are thereby precipitated and sub-microscopic crystallites of the new aluminium solid solution are formed. (c) The second increase in hardness is due to two processes occurring simultaneously: (i) the growth of the sub-microscopic particles to visible size, and (ii) the formation of fresh aggregates in strain-free areas by the further diffusion of copper atoms. (d) After maximum hardness has been reached and when softening has definitely set in, particles of α -CuAl₂ are to be observed in strain-free areas. The precipitated copper-rich particles are at random orientation with respect to the matrix, while particles of the α -CuAl₂ phase are oriented with respect to the matrix. (e) The polymorphic transformation α -CuAl₂ \rightarrow β -CuAl₂ takes place in the softened alloy with no increase in hardness.

The precipitation of the copper-rich aggregates is a discontinuous process, while the precipitation of α -CuAl₂ in alloys aged at temperatures higher than room temperature is a continuous process.

THE COLD WORKING OF HIGH PURITY ALUMINIUM ALLOY CONTAINING 4% OF COPPER AND ITS RELATION TO AGE HARDENING

By MARIE L. V. GAYLER, D.Sc.

THE new data described in the above paper dealing with the ageing of high purity aluminium alloy containing 4% of copper helped to throw light on the effect of cold work on the age hardening properties and on the relationship between the two processes, and as a result of experimental work data have been obtained from which the following conclusions are drawn:—

(1) Cold work accelerates the rate of ageing by an amount determined by the degree of cold work given.

(2) Microstructural changes have shown that the effect of cold work on a quenched specimen is to bring it into the fully aged state normally produced by ageing at room temperature; the effect of further ageing at room or higher temperatures has been related to conditions determined by the normal time-hardness curves.

(3) Lattice strain caused by cold work has been shown to be relieved by the formation of sub-microscopic (or microscopic, depending on the previous condition of the alloy and its ageing temperature) "crystallites" and, simultaneously, sub-microscopic precipitates of copper-rich particles.

(4) The course of ageing curves of cold-worked and aged material has been considered in relation to the amount of lattice strain the material is capable of withstanding. The inference has been drawn that measurement of lattice strain, resulting from the cold rolling of a soft-annealed specimen, may be associated with Brinell hardness.

(5) The mechanism of the relief of a strain caused by cold work is similar to that which occurs in relief of strains set up during age-hardening, i.e., by the formation of "crystallites."

CONTROL OF INTERNAL STRESSES IN HEAT-TREATMENT OF ALUMINIUM ALLOY PARTS.

By L. E. BENSON, M.Sc.

THE normal heat-treatment applied to many aluminium alloys and called for in many specifications involves quenching from a temperature in the region of 500° C. and subsequent precipitation hardening. What is not so well known is that this treatment may set up internal stress of dangerous magnitude. This stress arises from the differential cooling and contraction on quenching, the magnitude of the stress increasing with the mass of the part and the speed of quenching.

With parts of even moderate size, very high stresses can be generated. An example is given which shows a quenched and hardened cylinder in Duralumin S, 8 in. in diameter, which ruptured spontaneously on machining the ends. This example illustrates also the characteristic distribution of quenching stresses, namely, tensile stress in the interior balanced by compressive stress towards the outside, as would be expected and has been demonstrated already by other workers.

Clearly, the presence of high stresses is of great importance on account of the risk, not only of internal rupture, but of distortion on machining or in service, or of failure in service through unsuspected stress effects in addition to the calculated service stresses. The object of this paper, therefore, is to draw attention again to the risk of dangerously high stresses in quenched aluminium alloy parts, and to compare two methods of minimising the quenching stresses.

Experiments were made on wrought metal of D.T.D. 410, i.e., R.R. 56, having the following specification analysis: copper, 1.8-2.5; nickel, 0.6-1.4; magnesium, 0.65-1.2; iron, 0.6-1.2; silicon, 0.55-1.25; and titanium, 0.05-0.15%. The experiments which were carried out in the Research Department of Metropolitan-Vickers Electrical Co., Ltd., several years ago in connection with service contracts, concerned the effects of:—

1. Dimensional changes during precipitation-hardening on quenching stresses.

2. Stress relief accompanying, or subsequent to, precipitation-hardening on quenching stresses.

3. Solution-quenching-water temperature on internal stresses.

4. Stress-relieving treatment and of increasing quenching water temperature on mechanical properties.

As a result of the experiments, it is shown that the stress system developed on water-quenching aluminium alloy parts in D.T.D. 410 alloy is substantially unaffected by the subsequent precipitation-hardening treatment, since the temperature is ordinarily too low for stress relief to occur, and since precipitation-hardening is not accompanied by appreciable volume change. There

are two possible methods of reducing quenching stresses by modifying the heat-treatment procedure:—

1. The treated part may be given a final stress-relieving treatment; or, 2. The quenching may be made less drastic as, for instance, by increasing the temperature of the quenching water. The former procedure would probably be carried out most conveniently in practice by increasing the precipitation-hardening temperature. The former method is used by at least one manufacturer of Diesel-engine pistons, but the latter method appears to be preferable for general engineering applications, since it involves the least sacrifice of tensile strength and elastic properties.

Under the conditions of the experiments described, freedom from internal stress was obtained by quenching in water substantially at 100° C.; the tensile strength and 0.1% proof stress were then reduced by 4–5 tons/sq. in., and this treatment has been successfully used with very large forgings. Quenching in water at 85° C. produced a very useful reduction of stress with a sacrifice of strength and proof stress of only about 2 tons/sq. in., and might be suitable for certain work. It is suggested that the above considerations are applicable to other heat-treatable alloys of aluminium.

INVERSE SEGREGATION IN CAST MAGNESIUM ALLOYS

By R. J. M. PAYNE, B.Sc.

THE alloys most widely used in magnesium foundries in this country and elsewhere are essentially magnesium-aluminium alloys containing 8–10% of aluminium; small proportions of zinc and manganese appear as the only other intentional additions. In the course of the production of sand and die-castings in these materials over a period of years it had been observed, from time to time, that certain castings exhibited a patchy appearance after chromating in the R.A.E. 30-min. hot chromate bath. This non-uniformity of colour was seen on castings in the as-cast and solution-treated conditions; the colour contrast was, however more marked with the parts which had been solution heat-treated. Instead of acquiring the uniform, black colour which is normal for materials to these specifications, the castings referred to took on a piebald appearance, due to the apparent inability of certain areas to accept a chromate film. Improper preparation or inadequate cleaning of the castings had played no part in the occurrence of these features, which were reproduced exactly when the parts were rechromated. The effects were seen most often in gravity die-castings. With components of a given design, the light patches appeared with great regularity on particular parts of the casting. With sand castings the effects were small and much less frequently observed and occurred only on, or close to, those parts of the casting which had been chilled.

The results described in this paper were obtained after studying the problem. For convenience the subject is presented in two parts; the first recording how the difficulties encountered in the foundry were studied and overcome; while the second part details the observed phenomena and records further work of an experimental character.

It is shown that the grain-size of the material, the rate of cooling in the mould, and the presence of thermal gradients are the main factors governing the appearance of these segregation effects. The use of coarse-grained metal, low casting temperatures, and severe chilling are

all conducive to the occurrence of inverse segregation. With sand castings, and using the very fine-grained metal such as is obtained with the normal melting, superheating, and casting practice, no significant inverse segregation is encountered. With increasing grain-size the tendency to segregate becomes more marked, and with very coarse-grained material, such as may be obtained by the addition to the alloy of small proportions of beryllium, exudations of eutectic occur at the surface of unchilled sand castings. With gravity die-castings the effects are similar, but the speedier cooling brought about by the use of the metal mould makes slight segregation difficult to avoid, even with fine-grained material.

It is shown, that, in segregating, the aluminium is generally accompanied by other elements present as minor alloying additions or as impurities; silicon in particular, which is present in the alloy as magnesium silicide, may be strongly segregated at the surface of the casting and make its presence manifest by its bright blue colour.

The fact that a magnesium alloy cast under controlled conditions can behave in two ways, exhibiting or failing to exhibit inverse-segregation effects according to its grain-size, is of some theoretical interest; the significance of the observation is briefly discussed.

INTERCRYSTALLINE CORROSION OF ALUMINIUM-MAGNESIUM ALLOY RIVETS

By G. J. METCALFE, B.Sc.

THE possibility of developing aluminium alloys with age hardening characteristics and of producing a really strong alloy that is lighter than those of the Duralumin type has engaged attention for some years. Considerable interest has been shown in essentially binary aluminium-magnesium alloys, particularly in Germany, where they have been used to a greater extent than in this country. The susceptibility of the higher magnesium alloys to intercrystalline corrosion has, however, prevented their more rapid development, and research work during recent years has been concentrated mainly on resistance to corrosion.

From the point of view of corrosion-resistance the low-magnesium alloys are reasonably satisfactory, but as the magnesium content is raised the risk of intercrystalline corrosion increases. Susceptibility to intercrystalline corrosion may also develop when the alloys are heated for long periods at temperatures such as are likely to be encountered in the tropics and appears to be associated with precipitation of the β -phase at the grain boundaries.

Previous work on this subject is reviewed in this paper in which attention is particularly directed to a metallurgical examination of rivets that have failed in service, and the effect of tropical temperatures on the micro-structure and corrosion-resistance of rivets to Specification D.T.D. 303.

A number of service failures in aluminium alloy rivets containing 7% and 5% magnesium, which are described, are attributed to intercrystalline corrosion, probably accentuated by stress. Normally aluminium alloy rivets containing 5% magnesium are not susceptible to intercrystalline corrosion and in view of the extensive use of rivets in this material and the apparent susceptibility to stress-corrosion failure under tropical conditions, an investigation of the following features is described, using $\frac{1}{8}$ in. dia. rivets to Specification D.T.D. 303:—

A. The effect of prolonged heating at tropical temperatures on rivets in various heat-treated conditions.

B. The possibility of heat-treating rivets so as to prevent the formation of a continuous grain-boundary network of β -phase.

C. The resistance to stress-corrosion failure of sets of lap joints, each set riveted with rivets in a particular state of heat-treatment.

As a result of this work it is shown that prolonged heating at tropical temperatures of aluminium—5% magnesium alloy rivets results in grain-boundary precipitation of the β -phase in the form of a continuous network, the presence of which renders the material susceptible to intercrystalline corrosion. The formation of this network occurs more readily when the material is cold worked before heating at tropical temperatures. The results obtained are in agreement with the results of work on alloys of somewhat higher magnesium content by other investigators.

The results of mechanical tests have shown that even in specimens in which intercrystalline corrosion has penetrated almost completely through the rivet head, the shear strength of riveted lap joints is not seriously affected after 12 months' exposure to sea-water spray. Under service conditions, however, although rivets are usually stressed in shear, tensile stresses such as those resulting from internal stress or from panting of a panel are developed in the rivet shank. Since the rate of chemical attack at tropical temperatures will be greater than at the laboratory temperature at which the corrosion tests described were made, it is to be expected that under tropical conditions there will be very severe corrosion of the rivets and the heads will be liable to flake off.

THE RESISTANCE TO CORROSION BY SEA WATER OF SOME ALPHA-TIN AND ALPHA-TIN-ALUMINIUM BRONZES

By J. W. CUTHBERTSON, D.Sc.

AS a result of previous work it has been established that binary α -bronzes containing 10% or more of tin are highly resistant to corrosion by sea water and evidence has been given of their suitability for condenser tube service. It is known that aluminium additions to brass improves its corrosion-resisting properties and might be expected to have a similar influence on bronzes and this paper gives the results of a study of the corrosion-resisting properties of a number of tin and tin-aluminium bronzes to determine their suitability for condenser tubes.

From the viewpoint of resistance to corrosion the choice of a bronze for use as a condenser tube will depend on three main considerations: (a) The predominating corrosive conditions, (b) whether the alloy is to be used in the filmed or unfilmed condition, and (c) whether or not it is desired to restrict the tin content to a minimum.

The results of the tests on the fully annealed alloys indicate that for a constant aluminium content an increase in tin content is accompanied by an improvement in resistance to both impingement corrosion and deposit attack. With a constant tin content, raising the aluminium content increases the resistance to deposit attack, but when the tin content is less than 8% and as it approaches 5%, addition of aluminium cannot prevent a steady and ultimately very rapid deterioration in resistance to impingement attack. Binary bronzes

containing not less than 10% of tin have a very good general performance when properly made; addition of aluminium to these higher-tin alloys improves their resistance to deposit and simple immersion corrosion, but does not significantly increase their already excellent resistance to impingement attack. The real advantage of aluminium is revealed in the alloys of lower tin content, where it largely compensates for the deficiency in tin. The important point is that with less than 10% of tin the presence of aluminium is essential, whereas with more than 10% of tin the value of aluminium is, on the whole, small and diminishes rapidly as the tin content approaches the limit of solid solubility. Thus, ternary bronzes containing as little as 8% of tin, which is in any case the minimum safe amount, depend essentially on the presence of aluminium to enable them to withstand impingement attack. Ternary bronzes containing 10% of tin and around 1% of aluminium are shown to be in some respects superior to 10% tin bronze, but it is considered doubtful whether the benefit derived from the addition of aluminium is sufficiently great to justify the use of the ternary alloy.

Aeration of the sea-water is found to increase the rate of deposit and general attack of all the bronzes, but does not significantly alter the order of corrodibility. The deposit corrosion of cupro-nickel, and to a lesser extent that of aluminium brass, is profoundly affected by aeration, and the rate of attack of the former is increased to such an extent that instead of being markedly superior in unaerated water it becomes inferior to the more resistant of the bronzes; in aerated sea-water the approximate average rates of deposit attack (expressed in mg./sq. dm./day) are: bronzes 20–40, cupro-nickel 35–45, aluminium brass 25.

A simple pre-filming process has been developed, by means of which the resistance of the bronzes to impingement and general corrosion can be improved; under deposit attack the usefulness of the process is limited, but it is able to retard corrosion for a time.

Comparative tests on alloys prepared by normal methods of casting and from degassed melts, and on materials having variable and controlled grain-size, have established the importance of homogeneity of structure and fineness of grain-size in combating impingement attack.

CAPILLARY FLOW IN THE SOLDERING PROCESS AND SOME MEASUREMENTS OF THE PENETRATION COEFFICIENTS OF SOFT SOLDERS

By A. LATIN, Ph.D.

THE investigation described in this paper is concerned with a theoretical and experimental study of the dynamics of capillary flow as applied to the flow of liquid solders into joints consisting of parallel flat members. In soldering, a second liquid is usually present, in the form of flux residues, and whilst the presence of flux is in general necessary to ensure wetting and penetration, the residues themselves may offer resistance to flow. The effective value of the penetration coefficient under such conditions is of more direct practical application, and in the theoretical section of the present work a discussion is given of the basis on which measurements of this effective coefficient may be carried out. Expressions are also given whereby the manner of flow of solders in a great variety of soldering

operations can be precisely calculated. The experimental section consists chiefly of the results of measurements of the penetration coefficient for a number of soft solders, mainly in joints of copper, together with some results on tinplate.

INERT ATMOSPHERES AS FATIGUE ENVIRONMENTS

By H. J. GOUGH, C.B., M.B.E., D.Sc., F.R.S., and
D. G. SOPWITH, B.Sc., Wh. Sc.

IN a previous paper¹ by the authors it was shown that the optimum fatigue resistance of a metal is necessarily that indicated by fatigue tests carried out in air; the substitution for ordinary atmospheric conditions of a fairly high degree of vacuum produced in several cases a considerable increase in fatigue resistance. In a subsequent paper² an attempt was made to separate out the effects of some of the constituents of the atmosphere in order to ascertain the

¹ *J. Inst. Metals*, 1932, **40**, 93.

² *J. Inst. Metals*, 1935, **56**, 55.

cause of the decrease in fatigue resistance which occurred in the presence of air. Annealed copper and annealed 70:30 brass showed the most marked atmospheric effect. The effect of impurities in the atmosphere was investigated and from the results it was concluded that the presence of water vapour was necessary in order for the atmosphere to have deleterious effect on the fatigue resistance of copper, but that the effect was probably catalytic, the presence of oxygen also being necessary. In the case of brass, it appeared that oxygen, even in the comparative absence of water vapour, had a considerable effect, the effect of oxygen and water vapour together being greater. In order to complete the series of tests on the effects of the separate constituents, it was decided to investigate that of water vapour alone. This paper describes experiments made with this object.

The results on copper show that neither oxygen nor water vapour alone produce any appreciable decrease in fatigue resistance; those on brass are difficult to interpret, but suggest that the decrease is due, in approximately equal proportions, to nitrogen, oxygen, and water vapour, each acting independently.

Corrosion Inhibitors

A Symposium on Inhibitors for control of Scale and Corrosion in Water was held recently before a joint session of the Divisions of Industrial and Engineering Chemistry and of Water, Sewage and Sanitation Chemistry at the 108th Meeting of the American Chemical Society in New York, N.Y. Some of the papers presented, dealing with the use of inhibitors in metallic systems, are reviewed.

THERE are three ways by which the useful life of a metal may be extended: (1) By the use of a more durable metal or alloy; (2) by interposing a protective layer of some inert material, such as bituminous compounds, paint or portland cement, between the metal and its environment; and (3) by changing the environment so that there will be less tendency for it to react with and damage the metal. The papers in the symposium discussed inhibitors for industrial water supplies and for neutral aqueous solutions, and therefore come within the third category. Such papers also discussed the efficiency of inhibitors, particularly on bimetal systems and concentration cells.

In the first paper by U. R. Evans, fundamental principles in the use of soluble inhibitors were considered, and factors deciding between corrosion and inhibition discussed. When the immediate corrosion product is sparingly soluble, corrosion attack is likely to be stifled, but, when the immediate product is soluble but a secondary product is only sparingly soluble, attack will usually continue. In order to render water non-corrosive it is necessary to introduce some substance which will ensure that incipient corrosion leads to a sparingly soluble body and thus stifles itself. Most of the inhibitors used to-day for the treatment of cooling waters act specifically by smothering either the anodic or the cathodic reaction. Anodic inhibitors function by forming a sparingly soluble anodic product, while cathodic inhibitors form sparingly soluble products on the cathode areas. When the corrosion reaction is under cathodic control, anodic inhibitors, which are usually alkaline bodies such as sodium hydroxide, sodium

carbonate, sodium silicate or sodium phosphate, or chromates, are likely to be "dangerous" since, when added in sufficient concentration, they tend to localise attack but may result in intensified attack at those areas which continue to corrode. Cathodic inhibitors, such as calcium bicarbonate or zinc salts, are likely to be "safe," since they do not cause intensification of attack. They are generally less effective, however, in reducing the total corrosion reaction than are anodic inhibitors.

In a paper by R. S. Thornhill, data were presented showing the effect of zinc, manganese and chromic salts as corrosion inhibitors. Experiments on the addition of zinc sulphate, manganese sulphate and chrome alum to Cambridge tap water, with and without additional carbon dioxide added, showed the zinc and manganese salts to reduce the corrosion of steel by 20-30%. While zinc sulphate provided the most efficient inhibition, its use was associated with excessive penetration along the water line. Manganese sulphate, however, was free from this defect since the water-line zone was not attacked. Chrome alum was not inhibitive except at low concentrations. Since the chrome alum contained potassium sulphate, which is a corrosive material, experiments were also carried out with chromic chloride, added as the green variety to tap water with and without additional carbon dioxide and also to sodium chloride solution. These experiments confirmed that chromic salts were not inhibitive except at low concentrations. The experiments also showed that, if a metallic salt is to function effectively as a cathodic inhibitor, the salt should possess an insoluble hydroxide or hydrated oxide, the hydroxide should be precipitated on the metal and not at a distance, the deposit so formed should interfere with the cathodic reaction and not as

Reference: *Industrial and Engineering Chemistry*, 1945, Vol. 37, No. 8, pp. 702-749.

in the case of thick films of iron hydroxide formed on the cathodic area not inhibit the corrosion process, and the geometry of the situation in which the inhibitor is being used should be such as to avoid the deposition of corrosion products at air-liquid interfaces. As the water-line zone is not immune in solutions containing zinc and chromic ions, zinc and chromic salts must, under certain circumstances, be regarded as "dangerous" inhibitors.

Threshold treatment of water systems was dealt with by G. B. Hatch and O. Rice who showed that corrosion and the deposition of calcium carbonate and iron oxide in such systems may be controlled by treatment with very low concentrations of the molecularly dehydrated phosphates. For the prevention of scale, maximum efficiency is obtained by the maintenance of 2 p.p.m. of the glassy phosphates in water, and for the prevention of iron deposition the phosphate must be added before the iron-bearing water is exposed to air, a ratio of Calgon (a sodium phosphate glass having a phosphorus pentoxide content of 67%) to iron of 2 to 1 being generally required for this stabilisation.

When threshold treated waters are passed over metal surfaces, protective films are formed on these surfaces and the rate of formation of these films is a function of the rate of supply of the glassy phosphate to the metal surface. Absorption of the glassy phosphates upon solid surfaces also plays an important part in all of the applications of threshold treatment. Tests carried out from 4°-99° C. have shown that glassy phosphate films are protective over this range of temperature.

It has been found that the protective film formed as a result of the glassy phosphate treatment is effective for the protection of steel surfaces over a wide range of pH, and that the pH appears to have little effect upon the protective action of the film so long as its value does not drop appreciably below 5. Corrosion control is also not limited to ferrous metals as preliminary tests have shown that glassy phosphates exert an inhibitive action upon the corrosion of zinc, copper, brass and aluminium. The corrosion of lead has also been inhibited by the treatment, but the degree of inhibition did not appear sufficient to render a plumbosolvent water safe for drinking purposes at a pH value less than 6.

The protection of small water systems from corrosion was dealt with in a fourth paper to the symposium by W. Stericker who showed that the life of plumbing and piping fixtures in office buildings, houses, laundries, etc. can be greatly increased by the addition of small amounts of sodium silicates to the waters passing through them. Hot water can be treated by passing a small part of it over sodium silicate glass, and various methods may be used to feed sodium silicate solutions to cold water. In particular, laundries have found such treatment of valves with zeolite-softened water which is usually more corrosive than the corresponding unsoftened water. Recent developments have also shown that silicate treatment can be used in much longer piping systems than formerly and that there is no limitation on the distance to which silicate will carry provided a good solution is used. Examples are given of discrepancies between laboratory and field tests of silicate treatment of New York water, and data is also given of actual field tests showing improved conditions with steel pipe lines after seventeen years of treatment. Yellow brass piping which was subject to dezincification in localised areas was also considerably improved by sodium silicate treatment.

TABLE I.—RESULTS OF GALVANIC TESTS IN BAYONNE TAP WATER

Material	Jar No.	C'ple No.	Mg	Weight Loss		Current		Thickness	
				Normal Corrosion	Galvanic Corrosion	Average Current	Galvanic Corrosion	Max. at End	Average of 4 Deepest Fits
				Mg per sq. DM. per day millamp.	Mg per sq. DM. per day	Mg per sq. DM. per day	Mils.	Mils.	Mils.
Steel 0.67 sq. DM. Area	1	1	4818	—	30	1.7	64	53.6	0
	1	2	3740	100	—	—	—	54.2	0
	2	2	4363	—	15	1.3	51	53.7	0
	2	3	4185	107	—	—	—	54.1	0
	3	3	12	—	0	0.002	0.1	60.0	0
	3	4	15	0.4	—	—	—	60.0	0
	4	4	49	—	0.2	0.005	0.2	60.0	6
	4	5	39	1.1	—	—	—	60.0	7
Nickel 2.0 sq. DM. Area	5	5	3060	—	11	0.41	15	60.0	21
	5	6	1619	43	—	—	—	60.0	21
	6	6	1677	—	18	0.25	9	60.0	11
	6	7	1028	28	—	—	—	60.0	14
	1	1	4.6	—	—	—	—	—	—
	1	2	4.4	0.04	—	—	—	—	—
	2	2	5.6	—	—	—	—	—	—
	2	3	2.2	0.02	—	—	—	—	—
Nickel 2.0 sq. DM. Area	3	3	0.9	—	—	—	—	—	—
	3	4	0.4	0.004	—	—	—	—	—
	4	4	1.2	—	—	—	—	—	—
	4	5	2.4	0.02	—	—	—	—	—
	5	5	0.2	—	—	—	—	—	—
	5	6	1.8	0.02	—	—	—	—	—
	6	6	0.3	—	—	—	—	—	—
	6	7	0.5	0.004	—	—	—	—	—

* Uncoupled, normally corroding specimens.

The effect of chromate and lime additions to water on the galvanic corrosion of steel coupled to nickel was reported on by H. R. Copson. Laboratory tests were carried out with steel and nickel in Bayonne, N.J., tap water using sodium chromate and lime as inhibitors. The following couples were studied at 30° C.: 1 and 2, steel-Bayonne tap water (pH8)—nickel; 3 and 4, steel tap water plus 300 p.p.m. Na_2CrO_4 (pH8)—nickel; 5 and 6, steel tap water plus lime (pH11)—nickel. Separate, 4-litre, glass jars were used for each couple, and normally corroding uncoupled specimens were included in each jar. The nickel specimens were: $3 \times 5 \times 0.031$ in. and the steel specimens: $1 \times 5 \times 0.060$ in., making the area ratios 3 to 1. For the first 36 days of a 56-day test, the solutions were saturated with air and the specimens moved in a vertical circular path at the rate of 16 ft. per min. At 14, 28 and 42 days the solutions were changed, and all specimens in jars 1, 3 and 5 were rubbed. The results of these galvanic tests are given in Table I.

With a 3 to 1 area ratio of nickel to steel, the galvanic corrosion of the steel was appreciable but not excessive. Treating the water with 300 parts per million of sodium chromate practically inhibited corrosion, provided the steel was rubbed occasionally, otherwise pitting developed. Treating the steel with lime cut down the total galvanic effects but also localised corrosion, as part of the steel became passive and the rest was attacked at an excessive rate, with the result that the maximum rate of penetration was increased.

The use of the inhibitors of the corrosion of aluminium was reviewed and new data presented by C. G. Eldredge and R. B. Mears. Different types of substances have been found to be effective inhibitors in different types of solutions, acid, basic and neutral. Because of the high resistance to attack exhibited by aluminium in most neutral solutions, studies of inhibitions in acid and alkaline solutions are more readily conducted and effects are more easily measured than for tests in neutral

TABLE II.—SUMMARY OF NUMBER OF CASES OF PROTECTION BY INHIBITORS OF ALUMINIUM (2 S-1 H) ATTACHED TO COPPER IMMersed IN SODIUM CHLORIDE SOLUTIONS

Inhibitors	1% Inhibitor						0.1% Inhibitor					
	10 P.P.M. Sodium Chloride		50 P.P.M. Sodium Chloride		100 P.P.M. Sodium Chloride		10 P.P.M. Sodium Chloride		50 P.P.M. Sodium Chloride		100 P.P.M. Sodium Chloride	
	Definite Protection	Not Definite Protection	Definite Protection	Not Definite Protection	Definite Protection	Not Definite Protection	Definite Protection	Not Definite Protection	Definite Protection	Not Definite Protection	Definite Protection	Not Definite Protection
Soluble Oil 1	3a	—	1a	1a	—	1a	—	3a	—	1a	—	1a
Soluble Oil 2	2b	2	1a	1	—	3b	1a	5a	—	3b	—	2b
Soluble Oil 3	—	1	—	2b	—	1	—	2a	—	1	—	1
Sodium Disilicate	4b	—	—	—	—	2b	—	4b	1 slight	2b	—	2b
Sodium Metasilicate	1	—	—	—	—	1	—	2	—	1	—	1
Sodium Sesquisilicate	1	2a	—	—	—	1	—	2	1 slight	1	—	2
Sodium Chromate...	2a	—	—	2b	—	2b	1	6b	1a	3a	—	3a
Sodium Chromate + 40 P.P.M. Sodium Metasilicate	2a	—	1a	—	—	1a	—	4a	—	2a	—	2a
Sodium Chromate + 40 P.P.M. Sodium Disilicate	2a	—	1a	—	—	1a	1	3a	—	2a	—	2a
Soluble Oil 2 + 40 P.P.M. Sodium Metasilicate	—	—	—	—	—	1	—	—	—	—	—	—
Soluble Oil 2 + 40 P.P.M. Sodium Disilicate	—	—	—	—	—	1	—	1	—	1	—	1
Soluble Oil 2 + 40 P.P.M. Sodium Sesquisilicate	1	—	—	—	—	—	—	1	—	—	—	—

a—One of the specimens was attached to a large (1 × 4 in.) copper strip instead of to a small (0.5 × 0.5 in.) piece.

b—Two of the specimens were attached to large copper strips.

solutions. Chromates are effective in phosphoric acid but not in hydrochloric acid, while nitrogen compounds and pickling inhibitors that are effective for steel are usually more effective for aluminium in hydrochloric acid than in phosphoric acid. No very effective inhibitors for aluminium in sulphuric acid are known.

No very satisfactory inhibitors of attack of aluminium by solutions of sodium hydroxide or potassium hydroxide are known. In alkaline carbonate or phosphate solutions, silicates and fluosilicates are very effective, and in sodium hydroxide solution, colloids such as glue are stated to be effective. In solutions of sodium hypochlorite, sodium disilicate is effective, and it is also said to be effective in chlorine water. In neutral waters, chromates, silicates and soluble oils are most effective, and in neutral salt solutions chromates function by increasing the anodic polarisation.

One of the most difficult types of aluminium corrosion to inhibit is when aluminium is in contact with copper or some other cathodic metal in a solution which contains chloride. In laboratory tests, which were carried out, couples of aluminium and copper were exposed in solutions of 10, 50 or 100 p.p.m. sodium chloride, and soluble oils, silicates and chromates were used as inhibitors. In general, inhibition was obtained when 1% of inhibitor was present and when the chloride ion concentration was as low as 10 p.p.m. Additions of small amounts (40 p.p.m.) of sodium silicate to the sodium chromate were found to be advantageous. The result of some of the tests are given in Table II.

It is also stated that water may be an inhibitor of attack of aluminium in some nearly anhydrous organic chemicals, such as organic acids, phenols and alcohols, and that borates and phosphates are used as inhibitors in ethylene glycol solutions. Chromates have also been successfully used in alcohol solutions, and, for some cases, especially in insulation materials in contact with aluminium, chromates which are slowly soluble have an advantage.

In a seventh paper to the symposium, chromate corrosion inhibitors in bimetallic systems were considered by M. Darrin. The technology, rather than the theory of inhibiting this kind of corrosion by means of chromate

TABLE III.—EFFECT OF CHROMATE CONCENTRATION ON APPEARANCE OF PANELS (TAP WATER, 70° F., FULL SUBMERSION, pH 7.5-8.5)

Panels	Chromate Concentration P.P.M.					
	0	62.5	125	250	500	1,000
Iron:						
1 Yr. Aerated ...	Bad	Bad	Good	Exo.	Exo.	Exo.
2 Yr. Non-aerated...	Bad	Bad	Good	Exo.	Exo.	Exo.
3 Yr. Non-aerated...	Bad	Bad	Good	Exo.	Exo.	Exo.
Iron Contact Brass:						
1 Yr. Aerated ...	Bad	Bad	Bad	Good	Exo.	Exo.
1 Yr. Non-aerated...	Bad	Bad	Fair	Good	Exo.	Exo.
3 Yr. Aerated ...	Bad	Bad	Bad	Bad	Exo.	Exo.
Iron Contact Zinc:						
2 Yr. Non-aerated...	Fair	Good	Exo.	Exo.	Exo.	Exo.
3 Yr. Non-aerated...	Fair	Good	Exo.	Exo.	Exo.	Exo.
Galvanised Iron:						
1 Yr. Aerated ...	Bad	Good	Exo.	Exo.	Exo.	Exo.
2 Yr. Non-aerated...	Bad	Good	Exo.	Exo.	Exo.	Exo.
3 Yr. Non-aerated...	Bad	Good	Exo.	Exo.	Exo.	Exo.
Galvanised Iron and Copper:						
2 Yr. Non-aerated...	Bad	Fair	Good	Good	Good	Exo.
Aluminium:						
2 Yr. Non-aerated...	Fair	Exo.	Exo.	Exo.	Exo.	Exo.
3 Yr. Non-aerated...	Poor	Exo.	Exo.	Exo.	Exo.	Exo.

under conditions encountered in practice is described. The effect of time of exposure, temperature, aeration, submergence of panels, effect of initial pH, changes of pH during exposure, effect of silicate, effect of chromate concentration, film protection, cathodic protection, and effect of areas, are shown as they influence the corrosion of various bimetallic systems. Data include corrosion scores, weight loss, depth and type of pits, changes in pH, and chromate consumption. The effect of chromate concentration on the appearance of panels is given in Table III.

A study of the various conditions show that chromate is effective for combating bimetal corrosion in recirculating and quiescent water systems, and that it inhibits by anodic polarisation. Under some conditions chromate is assisted by cathodic inhibitors and also by silicates. In the case of a partially submerged panel, chromate does not protect at or just above the water line. At very low concentrations chromate may stimulate corrosion of ferrous parts.

Results obtained also show there are no harmful results from the use of excess chromate, nor is there an increased consumption, since the amount of chromate consumed in protecting a metal surface decreases as the concentration of the chromate is increased. Although the concentration required to inhibit is independent of the area of the metal surface which it is protecting, the rate of consumption of chromate is a function of the metal area as well as the concentration. Consumption is also increased by rise in temperature, lowering pH below 7.0, or by the pressure of reducing substances. Where there is an exposed cathodic metal, such as brass, a fairly high concentration of chromate is required to protect ferrous parts, especially if there are stagnant regions or old rust accumulations, but, in general, a moderate concentration (500 p.p.m.) is sufficient for the protection of ferrous parts of most equipment. Under some conditions, however, as in a rapidly moving stream which is not subject to local depletion of chromate, much lower concentrations may be employed.

Darrin also described practical applications of chromate inhibition for air-conditioning systems, refrigera-

tion brines, automobile systems, Diesel engines, power rectifiers, [and other recirculating and quiescent systems.

A progress report on a programme by the U.S. Army Corps of Engineers for treating potable water supplies to control scale and corrosion at army installations was also made to the symposium by R. H. Hanlon, A. J. Steffen, G. A. Rohlich and L. H. Kessier. A series of tests was carried out to determine the effect of various chemicals in preventing scale and corrosion under control conditions at one post and the results of these tests were applied to problems at many other army installations. In general, the progress made showed that the control of scale could be accomplished economically by threshold conditioning, and that the correction of corrosion difficulties, although not so pronounced as the control of scale-forming waters, could be accomplished by chemical conditioning. Certain positive evidences of protective films, layers or coating were observed, and the retardation of tuberculation and pitting of black iron pipes, heaters and tanks was noted although it was not so pronounced as that in galvanised pipes.

Polarographic Analysis

A SERIES of four papers was read at a symposium held by the Physical Methods Group of the Society of Public Analysts and Other Analytical Chemists in October, 1945. These have now been published.¹

In the introductory paper, "General Principles of Polarographic Analysis," by W. Cule Davies, the basic apparatus is described, and the relative merits of manual recording and automatic recording, both photographic and pen, are discussed. The precautions to be taken in the investigation of a new polarographic method are considered.

In the second paper, J. E. Page discusses "Biochemical Applications of Polarographic Analysis." He points out that while for many analyses the polarograph can produce better results than the alternative available methods, there should be a critical examination of the results obtained by a range of analytical techniques in every new problem, before recommending the polarographic method as the most satisfactory.

Various metals in biological fluids and tissues have been successfully estimated polarographically, examples being lead, arsenic, vanadium, zinc, cadmium and magnesium. However, it is doubtful, because of the complex pre-treatment, whether such methods offer any advantage over other techniques. But the estimation of antimony in blood or urine affords an example of a case where the polarographic determination is preferable. One merit of the procedure is that three- and five-valent antimony can be determined in the presence of each other.

The main advantage of the polarograph in biological work lies in its application to organic substances of biological interest. A sufficiently wide range of these is quoted to indicate that the instrument has an important place in the biological field.

A. S. Nickelson presents a paper on "Inorganic Applications of Polarographic Analysis, with Special Reference to Aluminium, Magnesium and Zinc." For

speed and accuracy, the polarograph is in many cases invaluable. The analysis of zinc and zinc-base alloys has been investigated in conjunction with the British Standards Institution, and methods for such determinations have now been published.²

A method has been developed, and is described, for the determination in aluminium of iron and copper up to 1%, lead up to 0.2%, and zinc up to 2%. The same methods may be applied to magnesium.

The fourth paper of the symposium, by R. H. Jones, is entitled, "Applications of Polarographic Analysis to the Examination of High Purity Selenium, Nickel and Cobalt Compounds." In the case of selenium dioxide, the impurities are concentrated, and a chemical separation is applied to divide the impurities into three groups: tellurium, copper and lead, nickel and cobalt. The copper determination may also be checked in the nickel-cobalt group.

For nickel and cobalt salts, polarographic determination is stated to be more rapid than standard methods for copper and lead, and the method also avoids chemical separations. These elements have been determined in nickel chloride, nickel sulphate, nickel formate and nickel ammonium sulphate, and in cobalt acetate, cobalt chloride and cobalt sulphate.

Nickel can also be determined rapidly in cobalt salts, with an accuracy of $\pm 3\%$ of the nickel content, the procedure being much less tedious than normal methods. Finally, the nickel / copper ratio in matter is determined polarographically during the extraction of nickel by the carbonyl process. This offers a rapid method of following the completeness of extraction. Such a determination can be made in less than half an hour, an obvious advantage in process control over the several hours of the gravimetric determination.

² Recommended Methods for Polarographic and Spectrographic Analysis of High Purity Zinc and Zinc Alloys for Die Casting, B.S. No. 1225, 1945; Polarographic and Spectrographic Analysis of High Purity Zinc and Zinc Alloys for Die Casting, I.M.S.O., 1945.

¹ Analyst, 1946, 71, 49.

War Losses and Patentees

S. T. MADELEY.

A YEAR after the Board of Trade had appointed a Committee, under the Chairmanship of Mr. Kenneth R. Sawn, K.C., to consider amendments to the Patent Act that Committee published its First Interim Report.

The Report deals with Section 18 (6) of the Act which enables a patentee to obtain, on suitable evidence, an extension of term of his patent on the sole ground of loss or damage due to hostilities between this country and another. As the evidence before the Committee was unanimous, on both the line of amendment necessary and the urgency of the matter, the Report was issued in April 1945.

A questionnaire was originally sent out by the Committee to individuals and bodies who are interested in the subject. We are only concerned with question 12 which is as follows: "Do you think any amendment, and if so what, is required in the practice and procedure in regard to applications or petitions for prolongation under Section 18 of the Act?"

A lot of information, oral and written was given to the Committee on which to base its review. Some of the evidence has been published. Let us take three such cases.

The Chartered Institute of Patent Agents said that it was strongly of opinion that applications under sub-section 6 should be dealt with by the Comptroller and supported by evidence in the form of statutory declaration and that the matter was urgent. It did not favour an automatic extension of all patents for a period equal to the duration of the War.

In its answer the Joint Chemical Committee stated that application under the sub-section should be made in the first instance to the Comptroller with an appeal to the Patents Court (an institution recommended by the Committee).

That section 18 (6) applications should be made to the Comptroller was the opinion also of the Trade Marks Patents and Designs and Federation, Ltd.

Before issuing its Report the Committee had had nineteen whole-day sessions.

In the Report it is pointed out that an application of the kind under consideration is made shortly before the expiration of the patent in question. Section 18 Sub-section 7 was added by the 1942 Act and permits of an application being made under sub-section 6 even after the date of expiration of the patent, and provides for more than one application for extension so long as the aggregate is not more than ten years.

The Committee Report states that sub-section 7 was not criticised. The provisions of present practice and costs were objected to.

An applicant now keeps his patent in force by paying all renewal fees. By way of originating summons he applies for extension and proves his war loss by affidavits. The Summons is in the due course returned and the application is advertised after directions to that end have been given by the Judge or Master in Chambers. Opposition can then be made.

The Comptroller of Patents is named as Respondent and the summons is served on the Solicitor to the Board of Trade who refers it to the Comptroller for close examination of all the documents as the latter is the custodian of the public interest in patent matters.

Observations made by the Comptroller and his views as to a justifiable extension are communicated to the Solicitor to the Board of Trade who passes on to the applicant's solicitor such of them as relate to irregularity regarding the application, or insufficiency or obscurity as regards the evidence. To the Comptroller is transmitted by his Solicitor to the Board of Trade any reply received. Advice as what answers should be sent are given by the Controller. Finally the Court is asked to fix a time for the hearing, at which the applicant is nearly always represented by counsel although he may appear himself. Counsel instructed by the Solicitor to the Board of Trade represents the Comptroller, who appears in the public interest, at the hearing. In any case the Applicant pays not only his own costs but those of the Comptroller (Solicitor and Counsel). If there is an opposition these costs may be much increased.

Generally simple and clear-cut issues are brought before the Court, which in nine cases out of ten grants such an extension as is thought suitable by the Comptroller. The cost for a simple and unopposed case of an average nature is from £150 to £200, including the Comptroller's costs. Oppositions are very rare. One or more applications may be necessary. Most patentees cannot afford such expense.

The Committee considered meeting the situation by an automatic extension of all patents for a time equivalent to the period of the War, but rejected this idea on account of the many difficulties and inconsistencies it would give rise to.

Another proposal not favoured by the Committee was one whereby the Masters should decide these applications when not involving serious doubt or difficulty concerning the determination of whether or not an extension should be granted and in the former case its length. This could be done on instructions by the Judge under existing rules of procedure without need for special legislation.

In the opinion of the Committee applications under section 18 (6) should be made to the Comptroller who should be empowered to deal with such cases. The applicant should be given the option of applying to the High Court following the precedent of section 32 (1) of the Trade Marks Act 1938. This deals in: the rectification of the Trade Marks Register. Applicants largely prefer application to the Comptroller in his capacity of Registrar. There should be an appeal from the Comptroller to the Patents Appeal Tribunal. Furthermore, at his discretion the Comptroller should be able to refer to the Court, for decision, the application under the sub-section when he is of the opinion that it is advisable so to do.

If the evidence satisfies the Comptroller and there is no opposition by others, there need be no hearing and the Patent could be extended by his Order. At a hearing the applicant might support his case through counsel, solicitor, patent agent or in person.

Applications should be made on a form stamped £3 and supported by evidence by way of statutory declaration.

The application should be advertised without fee only in the official Journal (Patents) and should be open to opposition.

The Comptroller should consider all the circumstances of the case (e.g. profits from foreign patents) and should be guided by judicial pronouncements made in decided cases. Licensees should not be allowed to apply under the section.

Cutting Fluids in Machining Operations*

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There is considerable divergence of opinion and a lack of agreement concerning the application of cutting fluid, yet the yearly consumption of undiluted cutting fluids in Great Britain alone is reckoned in millions of gallons. It is difficult to conceive that an industry will use this material unless it has definite evidence that either economies in production or improvement in the quality of the product result. The authors reviewed and discussed the types, properties, application and examination of cutting fluids in a paper before the Crewe, Liverpool and Manchester Sections of the Institution of Production Engineers, the main features of which are given in this article. The authors direct attention to many important aspects of the subject, the significance of which is not always fully appreciated in practice.

Laboratory Examination and Analysis of Cutting Fluids

The function of the chemist in the selection and use of materials comprises first a comprehensive survey of the properties required to evaluate materials for the purposes for which they are intended and second, the conduct of routine analyses designed to ensure the maintenance of predetermined standards of quality. Cutting fluids present no exception to this generalisation.

The survey of properties calls not only for analytical skill but also for specialist knowledge in application and for the development of accelerated tests, such as corrosion tests, intended to predict, in as short a time as possible, the service performance of a material over long periods.

In the case of cutting fluids the correlation of chemical properties and performance is still so incomplete that in choosing a new fluid, laboratory tests are not sufficient and they must be accompanied by a shop trial over a reasonable period. From the results obtained in shop and laboratory it may then be possible to reach a reasoned opinion on the merits of the fluid.

The first step in a chemical survey is to make a complete analysis to establish the composition. If the material is a soluble oil, the following components are generally tested for and determined:—Water, ammonia, alkali oxides, fatty acids both free and combined, rosin acid free and combined, fixed oils, unsaponifiable matter, volatile solvents—aliphatic or aromatic—alcohols, amides, alkali sulphates, alkali salts of sulphonated oils, phenols, wool fat and sulphur compounds other than sulphonates. Many other determinations may be called for but these generally present special analytical difficulties and call for the possession of special knowledge and skill on the part of the analyst. An outline of analytical methods applicable to the more common constituents has been given by Hall.⁶

In the case of neat oils, the usual determinations are: Specific gravity, flash point, viscosity, iodine value, saponification value, acid value, total sulphur content, ash, unsaponifiable matter, volatile solvents, phenols and water content, if any. Chlorine is now a possible constituent also. Salient characteristics of the separated fatty acids such as melting point, iodine value and refractive index are also determined. Correct interpreta-

tion of analytical results can be a useful guide to the choice and performance of the materials. For example, in the case of emulsions the water content is of importance from the cost point of view, and the nature of the emulsifier is a direct pointer to the probable stability of the mixture. The presence of sulphonated oils will suggest an emulsion of good stability but rosin acids are agreed to impart liability to gum. Petroleum sulphonates and naphthenates are among the newer types of emulsifiers and their presence may indicate high dispersive power. High free acidity is likely to cause greening of copper and corrosion of non-ferrous metals generally. In the case of emulsions intended for working steel, free alkali sufficient to give a pH of about 9.2 is desirable from the point of view of the inhibition of corrosion, but in excess of this amount free alkali can be objectionable. The nature of the emulsified oil is of importance; if it is wholly mineral the oiliness will be inferior to that obtaining if a proportion of fatty oil is also present and the nature and amount of fatty oil is an important factor in assessing both the lubricant quality and the justifiable cost of an emulsion.

As regards neat oils, specific gravity is an aid to identification and flash point an indication of fire hazard. Viscosity is of importance; low viscosity is desirable in compounds intended for high-speed cutting so that penetration into capillary interstices may be as rapid as possible. The classification of fixed oils is based on iodine value and this figure is therefore of value in identifying the oil present. It is also of general value in that the determination of the iodine value of the mixed fatty acids from a cutting oil will give some indication of the tendency of the oil to oxidise and gum and it is unsafe to use oils of iodine value greater than 90 if reasonable freedom from gumming is desired. The saponification value provides a means of differentiating between mineral and fatty oils, and acid value is related to corrosion troubles as in the case of emulsion oils. Free alkalinity should be absent.

"Active" sulphur has been proved to possess lubricating value and its determination is of importance therefore. The estimation of sulphur in this form presents some analytical difficulty, but an empirical method has been used by Boston and Zimmer.⁸ This method is based upon the "affinity" of active sulphur for copper; the total sulphur content of the oil is determined both before and after treatment with copper at an elevated temperature, which removes the active sulphur, the amount of which is given by the difference between the two figures for total sulphur.

* Continued from August issue, p. 218.

⁶ Boston, Gilbert and Kraus, *Trans. A.S.M.E.*, 1936, Vol. 58, p. 371.

⁷ Hall, *Machining*, 1936, Vol. 49, p. 41.

⁸ Hall, *Ind. Chem.*, 1934, Vol. 10, p. 45.

⁹ Lloyd and Beeny, *J.I.P.T.*, 1938, Vol. 24, p. 652.

¹⁰ Boston and Gilbert, *Trans. A.S.M.E.*, 1936, Vol. 58, p. 685.

Mineral and fixed oils should contain no ash but a soluble oil contains alkali oxides which appear as ash. The unsaponifiable matter usually consists almost wholly of the mineral oil. Water should not be present and volatile solvents are of doubtful value from the cutting point of view, their function is probably to increase stability and miscibility. Aromatic solvents are probably an indication of the presence of tar oil derivatives. Phenolic and cresylic constituents are present generally as antiseptics though they may be present in soluble oils as emulsifiers. It should be remembered that whilst some antiseptic is desirable, phenolics are skin irritants and cases are on record where the antiseptic has been the cause of trouble rather than a preventative.

The presence of chlorine in neat oils will usually indicate that an extreme pressure lubricant has been added, and in view of the exceptional performance of chlorinated compounds in this field, great importance attaches to the chlorine content.

The characteristics of separated fatty acids, such as iodine value and melting point, are of use in identifying the fatty oils. Such identification is essential since a definite grading as to lubricating value can be given to a neat oil from the knowledge that it is wholly lard-oil or lard-oil diluted with mineral oil or some other fixed oil either pure or diluted. Moreover, the price of such oils depends upon their composition and analysis is of value in showing whether oils are as claimed and not adulterated.

In addition to analytical work, special laboratory tests, as distinct from shop tests, are necessary to evaluate specific properties which cannot be predicted from or are not related to the chemical composition. With soluble oils, emulsification and rusting tests are typical examples. These oils are used at varying dilutions according to the nature of the application, and it is the custom to dilute with the water available in the factory to several dilutions covering the intended range, and observe the behaviour over several days. Separation of water, oil or sludge are typical observations. It is also of practical value to immerse test panels of the metals to be machined—say steel and brass—and observe for the development of corrosion products. These appear particularly at the liquid-air-metal interface. The presence of metal may also sometimes be a factor affecting the stability of the emulsion. Some solutions are susceptible to the manner of mixing and, in addition to adding oil to water, solutions should be prepared by adding water to oil. Freedom from tendency to corrode metal is an important desideratum of emulsions and soluble oil should not be accepted until it has been proved satisfactory in this respect. A valuable test of this type is one devised by Lloyd and Beeny⁹. Samples of the emulsions are allowed to drip at the rate of one drop per minute on to a cast-iron block which is milled out into recesses. The block is made from material similar to that used for lathe beds and in each recess are placed piles of steel and brass chips so that workshop conditions are simulated. The test is continued for three to four days, and after this period a satisfactory emulsion should have caused no corrosion.

Neat oils are less influenced by physical conditions than soluble oils and their properties are more readily predictable from their chemical composition. It is necessary, however, to make dilution tests if it is the intention to dilute with mineral oil and cold tests are desirable to ensure that no separation of solid matter will occur during storage when temperatures are low, since such separated solids may prove very difficult to

get into solution again. With the processed oils it is also advisable to carry out corrosion tests even if only of the simple test panel immersion type. Tests for the development of obnoxious smell are also of importance though the writers hasten to disclaim any knowledge of how to specify limits or even how to define the smells.

It must be emphasised that these laboratory tests amplify but do not replace practical shop cutting tests.

The desirability of routine checking of incoming deliveries is obvious and from the chemical point of view it is a relatively simple procedure compared with the laborious work required for the initial selection. Once the chemical nature is established it is necessary only to choose the salient chemical characteristics of the particular oil and make the appropriate tests to ensure these characteristics are maintained and that no harmful impurities creep in.

Typical check tests on a sulphonated oil are water content, total fatty matter, unsaponifiable matter, alkali oxides, total SO_2 , and free fatty acids. For neat oils the check tests may include specific gravity, viscosity saponification value, acid value and active sulphur.

Where large quantities of cutting fluids are being regularly used and circulated, the routine checking system should be extended to cover the maintenance of correct standards during use. For example, continued circulation of an emulsion of the milky type will result in a decrease in oil content and in practice this is probably responsible for much unsatisfactory work. Bacteria are accumulated and bacteria counts are desirable to ensure that reasonable limits are not exceeded. Routine maintenance also detects accidental contamination.

Though many other aspects present themselves, the foregoing covers the main features of the laboratory testing of cutting fluids.

Application of Cutting Fluids

To lay down hard and fast rules governing the application of cutting fluids to all cutting operations is impossible. The type of machine, the composition, type and setting of the tool, the cutting speed, and the nature and history of the material present so many variables that no generalisation can cover all combinations and the engineer must be left to make his own final decision.

The outstanding points to remember are, firstly that the use of a cutting fluid is not a magical solution to all the troubles encountered in metal cutting, absolving the engineer or machinist from responsibility in the design and set-up of the tool, and secondly that, having decided on the mechanical conditions, the choice of a fluid should be based on broad established principles and not on isolated shop trials. In many cases the results obtained by the use of a cutting fluid will not be spectacular but a definite reward will be obtained in the improvement of finish, increase in tool life, increase in cutting speed and reduction in power consumption.

Where low cost, good cooling and light duty are the main features, emulsions are usually selected such as for grinding, drilling, sawing, light milling and light turning. The degree of dilution varies with the particular cutting oil used but typical figures are 20 : 1 for screw cutting and automatic machines, 10 : 1 to 30 : 1 for turning, boring and sawing according to the severity of the operation, and 40 : 1 to 100 : 1 for grinding. Emulsions are sometimes avoided for brass and other non-ferrous metals on account of greening but expediency is often

the governing factor, and if emulsions are in common usage on the machines in question they may be used for brass, etc. Emulsions are disliked by the manufacturers of automatic and other expensive or complicated machines, who fear interference with the general lubrication of the machine and the incidence of corrosion. This point of view may be disputed and many such machines have run on emulsion for long periods without trouble, but it cannot be denied that any aqueous solution is a potential source of trouble and that therefore, straight oils are the only really safe usage on machines of this class.

Emulsions are frequently used also where the duty is heavy, but this would appear to be more a question of expediency and economy than of suitability, unless of course, the duty is associated with the need for coolant properties superior to those of neat oils. In applications of this type care should be taken to select a soluble oil with a high fatty oil content and the dilution should be low; say 5 : 1 to 10 : 1 for broaching and gear hobbing.

Low viscosity mineral oils are used for cutting non-ferrous alloys and for steels where the duty is not very severe and for general use on automatic machines. They eliminate greening and other corrosion troubles and at the same time their coolant effect is reasonably good since frictional heat is reduced and a good flow can be maintained with the relatively cheap oil.

Mineral-lard-oils are used widely for broaching and tapping of non-ferrous alloys, reaming of non-ferrous and ferrous metals, and gear cutting on automatic machines of all types; also on planing and turning machines and for all general cutting of medium severity. The need for their use is indicated when a better finish than that given by the straight mineral oils is desired. From practical observations the percentage of lard-oil should be varied within the limits of 5-40% though not more than the necessary percentage of lard-oil should be used because an excess over this amount adds to the cost and emphasises such disabilities as smell, and corrosive tendency associated with lard-oil. Lard-oil alone is still sometimes used—e.g., for gear shaving of ferrous metals, but for the most severe duties sulphurised oils are now generally used—e.g., for the machining of stainless and other high alloy steels, nickel, tough bronze, particularly with heavy feed cutting during gear roughing, broaching, deep drilling and reaming operations. The need for this class of lubricant is indicated by surface defects such as scuffing or scoring. In some applications their use is essential and they are capable also of performing satisfactorily the work done by less oily cutting fluids. They have, however, the disadvantage of blackening the work due to the formation of sulphides of the metal. It would appear that the only materials superior in performance to the sulphurised mineral fatty oils are the sulphochlorinated oils.

Outside the more well defined fields of application other cutting materials of widely differing nature are used for special operations. Tapping, apparently is a case in point and specialised lubricants such as tallow, beeswax, petroleum jelly, white lead in linseed oil, and zinc oxide in mineral oil are sometimes used. Hall⁷ prefers a lubricant made by dissolving an aluminium soap in mineral oil for this purpose.

In assessing the severity of an operation the following increasing order is generally accepted:—Grinding, sawing, turning, planing, drilling, automatic screw making, capstan lathes, multiple milling and boring,

deep drilling, gear cutting, reaming, gear shaving, threading, tapping and finally, broaching. To sum up, cutting operations increase in severity with respect to lubricant requirements: (a) from grinding to broaching in the order just enumerated, (b) as the toughness and hardness of the metal increases and (c) as the depth of cut increases. Lubricants increase in oiliness and extreme pressure characteristics and therefore in the order of increasing suitability for severe duty:—namely, soda solutions, emulsions, mineral oils, mineral-lard-oils, sulphurised oils, sulphochlorinated oils. In each of these an increase in the percentage of fatty matter also increases oiliness.

In many cases, emulsions are used for reasons of convenience in operations calling for severe duty lubricants. In such cases, care should be taken to choose a soluble oil with a high fatty content and to use a low dilution with water.

Some special cases call for comment distinct from the general cases dealt with above. Aluminium is sometimes cut dry, but a mineral oil-kerosene mixture is frequently used, or mineral-lard-oils on heavy cuts. Magnesium is always cut dry in this country, but American practice sometimes employs kerosene lard-oil mixtures. Cast iron is also cut dry except when a particularly good finish is required. Aluminium bronze, a metal hard to work, has been cut successfully with a new sulphurised soluble oil. Monel metal is best cut with a good quality emulsion and not with a sulphurised oil as might be expected.¹⁰ For very short tool life it is stated by Boston that emulsions are better in all cases than neat oil.

The best practice for cemented carbide tools is another controversial point. Opinion in general favours dry cutting and some have even prophesied that these tools herald the day when no cutting fluids will be used in any operation. A minority of users declare that the work done by carbide tips is improved by the use of emulsions. From general considerations, however, it would seem likely that if practical difficulties, such as of ensuring that the fluid shall wet and adhere under the extremely high cutting speeds, could be overcome, the use of a lubricant would be just as desirable with high-speed carbide cutting as with any other cutting operation. If emulsions are used with carbide tools, it is essential to maintain a continuous flow since temperature changes are harmful to the brittle carbide tips.

Strict adherence to the suggestions made would lead, it is realised, to a multiplicity of cutting fluids in shops where a wide variety of material is dealt with and in practice some scheme of standardisation, aiming at a minimum number of fluids which can preform with reasonable overall satisfaction the maximum number of operations, must be worked out. Generally, at least two fluids will be required. The first may be a good quality emulsion of average dilution, say 1 in 20, and this can be regarded almost as a "maid of all work."

The second will usually be chosen from the mineral-lard or sulphurised oils. The compromise must depend of course, on the class of work.

In shops in which a particular machine is required only to perform repetition operations on a single material, the need to compromise will not arise and the best fluid for that machine and operation can be chosen. In such cases it is advisable to affix to the machine a clear instruction card stating what fluid and dilution is to be used. It may be repeated that each case must be

considered on its merits and emphasised that careful selection based on sound principles must be accompanied by organisation and control of application.

Two other general points concerning cutting fluid practice are not always fully appreciated and should be mentioned. Reconditioning of the fluid is an important question. For less important work, settling tanks are sufficient, but for super-polishing and honing, an efficient filtering system is essential. On small plants, tanks and filters fitted to individual machines are practicable, but in large plant with a big through-put of fluid, more efficient arrangements make for economy. Batteries of machines are best served by a central reconditioning system which may with advantage, be centred round a centrifugal separator. In such a system it is desirable also to introduce some treatment to keep the bacteria count down.

The dilution of emulsions with hard water is the second point. Hard water destroys the soap present in

a soluble oil by forming lime and magnesium soaps which separate as a scum. This loss of soap gives a product weaker than was intended in the dilution or involves the addition of extra soluble oil, and in either case the balance of composition is disturbed and demulsification may result. Treatment of hard water with soda, trisodium phosphate or in a softening plant is advisable if no other soft water supply is available.

Whilst this paper has in many respects touched merely the fringe of the general subject of cutting fluids, it is hoped that attention has been drawn to the more important features.

Acknowledgment

The authors are indebted to Sir Arthur P. M. Fleming, C.B.E., D.Eng., Director of Research and Education, and to Mr. B. G. Churcher, M.Sc., M.I.E.E., Manager of Research Department, Metropolitan-Vickers Electrical Co. Ltd., for permission to publish this paper.

The Automatic Operation of Hardening Plant

INTERESTING AMERICAN DEVELOPMENT

THE automatic operation of furnace plant has on the whole been more widely developed in the United States than in this country, mainly in consequence of the larger production units which are in operation in that country. One of the most interesting war-time examples of such development which shows possibilities for peace-time work is one for the heat-treatment of rifle barrels of S.A.E. 4150 steel weighing 5 lb. each, and which would obviously serve also for such work as long spindles and shafts. This plant was put down for one of the main U.S. arsenals by the Lindberg Engineering Company, of Chicago, and its method of

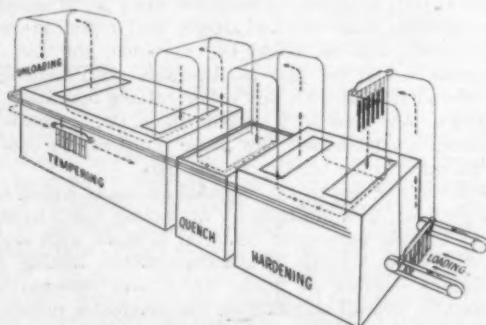


Fig. 1.—Diagrammatic sketch showing path taken by rifle barrels in heat-treating unit at Springfield Armory.

operation is diagrammatically illustrated by the drawing Fig. 1. The complete plant is 50 ft. long by 13 ft. wide by 19 ft. high, the hardening furnace being suitable for a temperature of 950° C., this being followed by a quenching tank equipped with cooling system and pumps, the final unit being a forced convection tempering furnace suitable for a maximum temperature of 770° C. The whole is operated by two women.

The work is first loaded on hangers which are picked up by tongs, the necessary set-up being shown by Fig. 2, from which it will be seen that 11 barrels are accom-

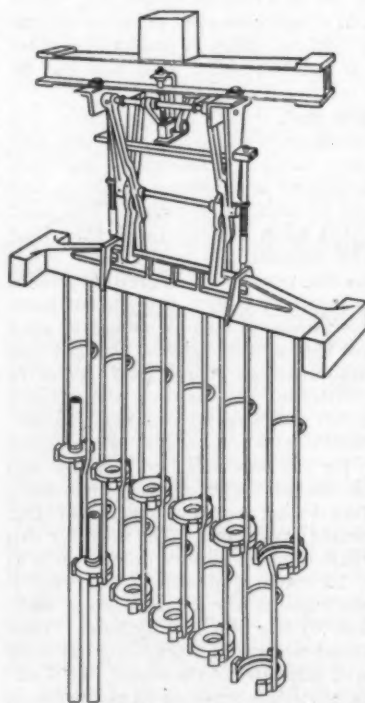


Fig. 2.—Arrangement of hangers and tongs.

modated in each hanger. Two short lengths of endless conveyor chain move the load immediately under the first set of lifting tongs, the movement being controlled by limit switches placed in series. Four timing devices control the operation of the automatic cycle; the first determines the length of time each load is maintained in the hardening and tempering furnaces; the second the time between the removal of the heated load from the hardening furnace and its immersion in the quenching tank; the third the length of time in the quenching tank; and the fourth the time between the

removal of the blanks from this tank and their entrance into the tempering furnace.

It is stated that the adoption of this automatic method of heat-treatment has practically done away with the re-hardening of improperly treated work, and, out of several hundreds of thousands of pieces, re-quenching or re-tempering was only required in the case of a few batches of work which were put through as samples. The plant is gas-fired, using town gas of a calorific value of 530 B.T.U., and the average consumption per hour taken over the whole plant is 4,300 cubic ft.

MICROANALYSIS

CHEMICAL AND PHYSICAL METHODS

APPARATUS METALLURGICAL APPLICATIONS TECHNIQUE

WE recently had the pleasure of meeting a Continental microchemist who has come to this country with the laudable aim of touring laboratories and of getting into touch with people, so as to gain that indefinable advantage of scientific intercourse which can never be gained from books and journals only. To arrange the visit, it is regrettable to have to note, required just one year. Although presumably scientists of first rank can pass fairly freely back and forth from here to the Continent and America, it would appear that there is a basis of procrastination and delay for the general run of scientists. This is bad in many ways. Rather than face the trouble of arranging a trip which is not dictated by urgent business reasons, most scientists would probably continue to do without the contact with their colleagues in other countries. The few who persist will undoubtedly be somewhat soured by their trials before they finally manage to set out. We have, for so long, been cut off from our Continental and American fellow-workers that we should make every effort to re-establish contact over the widest possible field. It seems, if one can believe the daily Press, not unduly difficult to visit Switzerland in order to spend a holiday. It may be equally easy to visit Switzerland—or America—to talk to microchemists. Looking in the reverse direction, for this is one of the instances where to give is as valuable as to receive, we don't expect that any Continental scientist, merely by taking thought, a ticket and a plane, will promptly arrive in this country. But one year seems a rather liberal budget of time for the necessary investigations and arrangements.

Problems Concerning the Microchemical Balance

Part IV.—Sensitivity and Precision

By David W. Wilson

A great deal has been written about the factors underlying the accuracy with which the microchemical balance can be used. Some of the accounts are so optimistic as to give an entirely misleading idea of the capabilities of the balance. Many are clouded with lists of precautions for which no adequate reasons are given. Some are contradictory in the emphasis which they lay on individual factors. In this account is has been the aim of the writer to sift this published information critically, to present the most reliable and useful portions of it, and to include such extensions from his own experience as are thought to be of value to the operator of a microchemical balance. The next part in the series will deal with the practical aspects of the determination of the capabilities of the balance, including the calibration of the balance and of the weights.

TO make full use of the microchemical balance the operator must know its capabilities and also its limitations. He must be able to make the fullest use of its delicate construction, and at the same time be able to estimate what degree of accuracy his results are likely to attain. He must, in fact, be able to push the balance to the limit of its powers, and know when that limit has been reached.

To achieve this, he must have not only a knowledge but also a sound understanding of the various factors which prevent the realisation of the highest possible accuracy, and must be able to keep a constant check on the performance of the balance when it is used under everyday conditions.

When the balance has been installed under the best possible conditions¹ and cleaned ready for use², its sensitivity and precision must be determined. In theory, neither should alter with use, but in practice slight alteration of sensitivity and diminution in precision may be expected with long-continued use,³ so it is advisable to check both values at intervals depending on the use made of the balance.

Both values must, naturally, be determined under the conditions which will be employed during the routine

1 C. L. Wilson, *Problems Concerning the Microchemical Balance—Part I—Installation*, METALLURGIA, 1944, **31**, 1014.

2 D. W. Wilson, *Problems Concerning the Microchemical Balance—Part II—Cleaning*, *ibid.*, 1944, **32**, 85.

3 C. L. Wilson, *Problems Concerning the Microchemical Balance—Part III—Construction*, *ibid.*, 1946, **34**, 219.

use of the balance. If the main causes of inaccuracy are understood, then the general rules to be observed in using the balance will be obvious. They are, in effect, merely extensions, due to greater sensitivity, of the rules observed with a good analytical balance.

Vibration must be minimised, and suitable methods of installation to effect this have been described¹. Such commonsense precautions follow as the gentle release of the beam and the avoidance of any contact with the balance-case during weighing.

Draughts must be absent, and the provision of an outer case² may achieve this if perfect location of the balance is impracticable. The importance of the draught due to the breath of an operator too intent on close observation must not be overlooked, and air-currents in the balance-case must be allowed to subside before weighing is begun.

Temperature gradients have, perhaps, the most serious effect on the accuracy of a weighing. Benedetti-Pichler⁴ states that work should be interrupted if the temperature of the balance rises by 0.3°C . during weighings. Proper precautions to limit the effects of outside sources of heat or cold will have been taken in mounting the balance¹. The following precautions applicable to the operation of weighing must also be observed. The object to be weighed should be left in the balance-case for a period varying between 5 and 20 minutes according to its nature. The doors of the case must be left open for 15 minutes before weighing to equalise any temperature gradients. The importance of heating effects due to the operator cannot be over-emphasised. He should take up his position only when actually engaged in weighing. He should sit squarely in front of the balance, as far away from it as is consistent with good observation of the pointer. When one hand approaches one side of the balance, either for placing the object or tare, or for adjusting the rider, or for releasing the beam if the handle lies to the side, the other hand should be used in a symmetrical movement on the other side in order to equalise the temperature effect. (Readers of a recent advertisement for a microchemical balance will note that in the photograph the operator has allowed her sense of balance from an artistic point of view to overcome, in this respect, her sense of balance from the gravimetric aspect. That this precaution is not inconsequent can be shown by determining the deflection of the balance, placing one hand near the side door for a few seconds, and redetermining the deflection). The operator's note-book should be placed directly in front of the balance and as far away from it as possible. Weighing should be carried out as quickly as possible.

The position of the rider on the rider-scale is of the utmost importance. The care taken by the manufacturers to provide equally-spaced and carefully-cut notches is nullified if the rider does not occupy its correct position in the notch—upright, at right-angles to the beam and in the lowest position in the notch. Various shapes of rider have been proposed as improvements on the usual design, but not all of them are successful. If the shape is symmetrical and so balanced that only the shoulders are in contact with the beam, and is flat (it may be flattened by manipulation with the forceps, or by pressure between folds of paper), the conventional rider can be used satisfactorily. After being placed in position, it should be joggled from both sides with the

rider hook so that its final position is the correct one. Inability to reproduce the position of the rider accounts for a considerable part of the lack of precision attainable with the balance.

Method of Weighing

Weighing is invariably carried out by the method of short swings. Instead of using the balance as a null-point instrument, as is usual with an analytical balance, the object is balanced with tare and rider to the nearest 0.1 mg . The extent to which the swings of the pointer are displaced is noted, and this is converted into weight by a previously ascertained calibration of the divisions on the pointer scale in terms of weight. This weight is then added to or subtracted from the weight indicated by the tare and rider.

The pointer scale is normally divided into 12 marked divisions to the left of the zero, and 12 to the right. Pointer movements are estimated to the nearest tenth of a marked division, so to avoid using a decimal point each marked division is in practice regarded as 10. Divisions to the left of zero are regarded as negative, and to the right as positive. The pointer scale, therefore, reads from -120 to $+120$.

The deflection of the pointer (sometimes called *deflection difference* or *deflection sum*) is the algebraic sum of the turning points (or *points of inflection*) of the pointer during one complete swing of the beam, corrected for friction. An example will make this correction clear. Suppose that under weighing conditions the pointer turns at the following three consecutive points on the scale: $-42, +29, -40$. The values of the two negative points are averaged, giving -41 . The "perfect" swing of the balance, that is the swing corrected for the friction which causes each swing to be shorter than the previous one, is between -41 and $+29$. The sum is -12 , hence the deflection is -12 , or 1.2 marked divisions to the left of the zero on the pointer scale. (Another definition of the deflection is: one point of inflection of a perfect swing which has zero for the other point of inflection. This will readily be appreciated by following a series of decreasing swings as an example, and it will also be seen from this definition that the value of the deflection is twice the value of the zero point—i.e., the reading on which the pointer would, if allowed, come to rest. In practice, however, the zero point is not used, and these considerations have no practical application to the evaluation of a weighing).

In practice, a swing of an amplitude of about 50 units on the pointer scale is chosen. The first two complete swings are disregarded, and the next point of inflection on the left taken as the first reading. Until considerable practice has been obtained, it is recommended that 6 points of inflection, 3 on the left and 3 on the right, be noted, so that an average value for the deflection can be obtained, and errors in reading the pointer position will be obvious. The values are conveniently noted in the following form:—

	+
52	38
50	36
47	33

and the averages inserted between the parent figures. If an average does not come to a whole number, the

⁴ Benedetti-Pichler, *Introduction to the Microtechnique of Inorganic Analysis*, New York, 1942, p. 181.

nearest whole number either above or below the average should be taken, and the same procedure followed consistently. In the example the whole numbers below the average in such cases have been taken. The averages should be underlined so as to distinguish them if subsequent reference is needed. Then the deflections are calculated, noted in the centre, and averaged:—

				+
52				
51	..	-13	..	38
50	..	-13	..	37
48	..	-12	..	36
47	..	-13	..	34
				<u>33</u>

Average deflection = -13

With practice, it will be necessary only to set down 3 consecutive points of inflection, after, of course, neglecting the first two complete swings as before.

Sensitivity

The sensitivity of a balance is defined as the weight required to change the deflection 1 unit (one-tenth marked division) on the pointer scale. (Some workers prefer the definition: the deflection produced by moving the rider 0.1 mg. This value, although it has the advantage of being a whole number, generally about 100, must be changed to the above form—its reciprocal—before being of direct application in evaluating a weighing). It is obtained by observing the deflection produced by moving the rider 0.1 mg. on the rider scale, and dividing this value into 0.1 mg. For example, if by moving the rider from zero to 0.1 mg. (1 notch) on the rider scale the deflection is altered by 88 units on the pointer scale, then the sensitivity of the balance is $\frac{0.1}{88}$ mg., or 0.0011 mg. The fourth decimal place is of

no significance until larger deflections are considered: a deflection of 6 units would correspond to a weight of 0.007 mg. In practice, as will be seen in the next article in the series, several weighings are performed with the rider at each position, and the averages taken for calculation.

The sensitivity of most microchemical balances is adjusted by the manufacturers to about 0.001 mg. It is seldom exactly this value, but is generally near it. It should remain constant with all loads up to the maximum (usually 20 gm.), but in investigating the performance of a balance this should be checked, using various loads, in the manner to be described. Altering the sensitivity by means of the vertical screw on the beam is an operation requiring considerable skill and is best avoided. If the sensitivity is increased above a certain value, the balance will become unstable and reproducible weighings will be impossible.

Precision

A microchemical balance may have a sensitivity of 0.001 mg., and yet not be capable of reproducing a weighing to less than 0.005 mg., even under ideal conditions. Many factors contribute to this, probably the most potent being the positioning of the rider. A 5 mg. rider has only to be about 0.008 mm. out of position to alter the weighing by 0.001 mg. on an 8 cm. balance beam, according to Pregl⁵.

It is, naturally, important to know to what extent one can rely on an individual weighing on a particular balance—that is, to know the precision of the balance. This is determined, as will be described in detail in Part V of the series, by performing a number of consecutive weighings of the same object under the conditions which are observed in the routine use of the balance. Each weighing must be an individual one, so the rider must be removed and replaced before each determination. The weighings are conveniently recorded as deflections on the pointer scale—conversion into weight will follow.

The average of these weighings is calculated, and the difference of each individual weighing from the average is found. A simple method of calculation is to take the arithmetical average (i.e., neglecting their signs) of these differences, which gives the average deviation of a single weighing from the mean value (which is taken, naturally, as the most accurate value). The example below shows the calculation of this average deviation from a series of ten weighings, recorded as deflections in the units of the pointer scale. This average is converted into weight by multiplying by the sensitivity of the balance. The average gives some idea of the accuracy which can be expected from a single weighing.

(This method of calculating the precision does not fully utilise the data given by the weighings performed. A more complete method of treatment is to determine the standard deviation of the weighings, given by

$$\sigma = \sqrt{\frac{\sum d^2}{n-1}} \text{ where } \sigma \text{ is the standard deviation, } d \text{ is}$$

the difference of each weighing from the mean, and n is the number of weighings performed. The standard deviation of the weighings in the example has been calculated below. Tables⁶ can be consulted showing the probability of a weighing lying outside particular limits from the true value. Examples are:—1 in 20 results will probably lie outside $\pm 1.96\sigma$; 1 in 100 outside $\pm 2.58\sigma$; 1 in 1,000 outside $\pm 3.29\sigma$. If a weighing is performed several times, and the average taken, then

the limits are multiplied by $\frac{1}{\sqrt{n}}$, where n is the number of weighings performed—e.g. if the average of three weighings is taken, the limits for 1 in 20 would be $\pm \frac{2.58\sigma}{\sqrt{3}}$. Some writers use a formula for "probable error" in this connection. This is not recommended⁶

Example: Rider at zero; 10 gm. on each pan:

Deflection	Deviation of each Deflection from Mean	d^2
+4	2.8	7.8
+2	0.8	0.6
+1	0.2	0.0
+4	2.8	7.8
+3	1.8	3.2
0	1.2	1.4
-2	3.2	10.2
0	1.2	1.4
+1	0.2	0.0
-1	2.2	4.8
Total ...	+12	16.4
Average ...	+1.2	1.6

Arithmetical mean deviation = 1.6

If the sensitivity = 0.0011 mg.

Arithmetical deviation in mg. = 1.6×0.0011 mg.
= 0.0018 mg.

Hence the average deviation of the above weighings from the mean weighing is ± 0.0018 mg.

⁶ Fisher and Yates, *Statistical Tables for Biological, Agricultural and Medical Research*.

⁵ Pregl, *Quantitative Organic Microanalysis*, Fourth English Edition, revised by Grant, London, 1946, p. 13.

Calculation of standard deviation:

$$\begin{aligned}\text{Standard deviation} &= \sqrt{\frac{\sum d^2}{n-1}} \\ &= \sqrt{\frac{57.2}{10-1}} \\ &= 2.03.\end{aligned}$$

If sensitivity = 0.0011 mg.

Standard deviation in mg. = 2.03×0.0011 mg.
= 0.0022 mg.

(Hence 1 in 20 weighings will probably be more than $\pm 1.96 \times 0.0022$ mg., or ± 0.0043 mg., from the true weighing; or alternatively 95% of weighings may be expected to lie within these limits).

The sensitivity of the balance must, of course, be calculated in order to evaluate the weighings. Its value, however, can be a misleading figure, as in general a balance has a precision which limits the accuracy to several times the sensitivity figure.

Chromatographic Analysis

FOUR papers dealing with chromatographic analysis, and read at the February meeting of the Physical Methods Group of the Society of Public Analysts and Other Analytical Chemists, have now been published.¹ The first of the papers, "General Principles of Chromatographic Analysis," by F. A. Robinson, serves as a general introduction to the symposium. The range of substances which have been separated by this technique is reviewed, and a brief description of the usual operations given, including reference to the methods of observing the positions of colourless bands on a column. The activity of various adsorbents, and methods of standardising activities are also discussed, as well as the relative behaviours of various solvents. Reference is made to the newer developments in chromatographic technique—fluid chromatography, displacement chromatography and boundary methods, reverse chromatography, the separation of substances in the vapour phase, ion-exchange columns, and partition chromatography. Brief mention is made of applications to inorganic separations. Finally, the rather undeveloped state of adsorption theory as applied to analysis is commented on and reviewed.

"Partition Chromatography" is described by R. L. M. Syngé. In this work, which is not dependent on true adsorption, but rather on partition phenomena, a column, such as silica-gel, is used to support an aqueous phase. The substance to be separated, borne in an organic solvent, is then passed over the column, the close contact between the two phases allowing a distribution of the solute to take place. After passing over the column, the result is much the same as if repeated extractions had been made. A banded structure results and the separation to be obtained is often of high efficiency. The rate at which a band moves down the column is determined by its effective distribution isotherm between the stationary particles of the column and the moving phase. An interesting development of this work is an ultra-micro technique in two dimensions—i.e., on paper. The aqueous phase is suspended on cellulose, in the form of filter paper, and is developed by a suitable solvent into a number of fractions, occurring as spots at various heights on the paper. The paper can then be turned through 90° and yet another solvent used for further development. This splits each fraction already obtained into a number of further fractions or spots, so that a characteristic arrangement of spots on the paper is obtained. In the separations quoted, the paper was then sprayed with colour reagent, which showed up the position of the spots. Partition chromatography has, as yet, been applied to a limited range of substances. The only columns so far used have been silica-gel, starch grains and cellulose. Further wide

developments in this technique are to be anticipated.

K. A. Williams in his paper deals with "Chromatography in the Analysis of Fatty Oils." Early separations, dealing only with unspontifiable constituents, have been extended to cover the other portions, so that methods are now available for free fatty acids, carotene, xanthophylls, hydrocarbons and so forth. While a complete analysis is a very lengthy process, and not always justified, simple methods are available for use in commercial analysis, and are described. It is stressed that a quantitative basis is needed for determining the relative affinities of solvents and adsorbents for solutes.

Finally, F. R. Cropper describes "Some Applications of Chromatographic Analysis in Industry," with special reference to dyestuffs and related substances. Standardisation of alumina for analytical purposes is described. The activity can be checked by use of a standard solution of the three azo compounds, azobenzene, benzene-azo- β -naphthol, and *p*-dimethylamino-azobenzene, checking the position of the bands after washing with a known amount of solvent. Chromatography has been applied to the control and estimation of impurities in dyestuffs, the separation and identifications of compound dyestuffs, and the determination of anthracene in coal-tar and coal-tar distillates. This last involves the use of ultra-violet light for following the position of the anthracene on the column.

Acid-washed alumina for acidic materials or substances which are unstable in the presence of alkali, and other adsorbents, also have their uses. Filter paper has been extensively applied for testing the quality of dyestuffs intermediates, using large paper circles placed between two glass plates, the top one of which has a small perforation. A drop of the solution, added through the hole, is washed with water or another suitable solvent, and the separated substances form concentric circles which can be compared with standard papers made up from known mixtures. For example, it is possible to determine the range of 0.4% of G acid in R acid with an accuracy of 0.5.

International Tin Conference

THE United Kingdom Government, after consultation with the Governments of the United States, Bolivia, Belgium and the Netherlands, has invited the main tin-consuming and tin-producing countries to an International Tin Conference in London. The countries invited are Belgium, Bolivia, China, France, the Netherlands, Siam, U.S.A. and U.S.S.R. The object of the conference is to consider the prospective world tin position and whether any continuous inter-governmental study of that position is necessary.

It is hoped that the conference will open about October 8th.

¹ *Analyst*, 1946, 71, 201.

Ductile Titanium

A Composite

THE applications of titanium for structural purposes have not yet been developed and its commercial exploitation has been largely confined to the chemical industries and to the production of paints and pigments largely due to the difficulties that lie in the way of preparing the pure ductile metal. Published reports, however, indicate that ductile titanium can be prepared and possesses some unique properties, and this, together with the occurrence in the United States of several important titaniferous deposits, has led the Bureau of Mines to investigate processes for the production of metallic titanium, methods required for its fabrication and the properties that may be produced in the metal.

R. S. Dean, J. R. Long, F. S. Wartman, and E. L. Anderson¹, after reviewing methods of preparing metallic titanium, concluded that the Kroll process was the most practical for large scale operations. Briefly this process

consists of the reduction of titanium tetrachloride with magnesium at a temperature of about 800° C. The reaction mixture, consisting of titanium, magnesium chloride, and unreacted magnesium, after cooling is crushed and leached. The resulting granular titanium is ground wet, re-leached to remove the magnesium, dried, and consolidated by powder methods or by a special arc process.

Laboratory investigation of the preparation of ductile titanium by reduction of titanium tetrachloride by magnesium on an apparatus giving small reductions progressed satisfactorily and led to an expansion in the scale of the work and the size of the reduction unit. Batches of titanium powder up to 15 lb. were produced without encountering any technical difficulties that would prevent the expansion and use of the process on a large scale. The granular metal product was produced in a high state of purity, containing about 25 cc. of hydrogen per gram of metal and 0.50% of magnesium, both of which were completely removed by sintering at 1,000° C. in high vacuum. It was also found that the powder might contain up to 0.1% of iron and a few

tenths of oxygen as oxide. No information was available on the silicon content but it was believed to be less than 0.1%. These latter impurities were not present in sufficient amount, however, to interfere with the ductility of the metal.

The powder obtained was consolidated by pressing into compacts at a pressure of 50 tons per sq. in. and sintering at 1,000° C. in a vacuum of 1×10^{-4} mm. Hg. These sintered compacts were ductile, could readily be deformed cold and could be made into sheet and bar by normal fabricating methods. Annealed material had a tensile strength of about 36 tons per sq. in. with 28% elongation and a Rockwell A hardness of 55. After 50% reduction by cold work the tensile strength was 55 tons per sq. in., the elongation 4%, and the Rockwell A hardness 65. The metal also had good corrosion resistance, being similar to 18/8 stainless steels in this respect. It did not tarnish nor were the physical properties affected after exposure for thirty days to a salt spray test. The consolidated material was also quite stable and could be heated to 800° C. in air without taking fire.

The data just reported were obtained on metal fabricated by a fixed procedure, standardised for the purpose of control of the reduction, and were representative only of material fabri-

cated under these conditions. An investigation of other methods was carried out by R. S. Dean, J. R. Long, F. S. Wartman, and E. T. Hayes², in which the consolidation of the powder by pressing and sintering was conducted as before, but in which all efforts were centred on

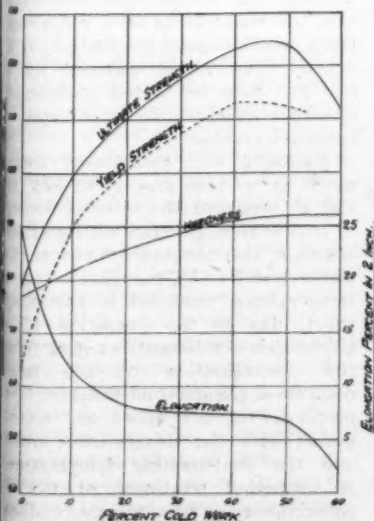


Fig. 1.—Physical properties of cold-worked titanium.

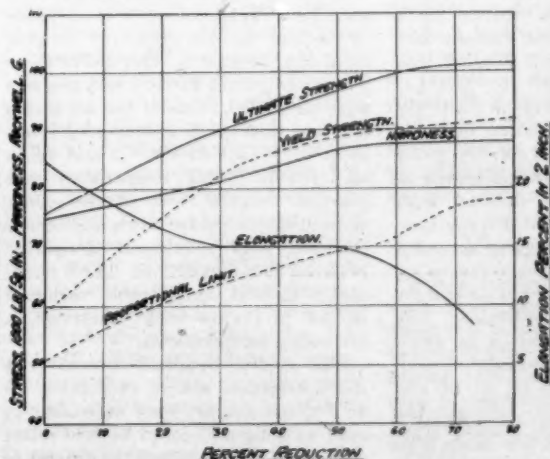


Fig. 2.—Physical properties of hot-worked titanium.

² Metals Technology, 1946, Vol. 13, No. 2 and A.I.M.M.E. Technical Pub. 1965, pp. 1-17.

fabrication methods for those powders and the properties produced by them. Sintered compacts were finished into $\frac{1}{16}$ in. sheet by sequence of forging, cold-rolling and hot-rolling procedures, and hardness, density, microstructure, and tensile properties were determined at various stages in the working and annealing. Some of the results obtained are given in Figs. 1 and 2. Resistivity measurements were made on a few bars and drawn wire.

It was found that the sintered compacts had a density of 4.30 and a tensile strength of 83,000 lbs. per sq. in. (37 tons per sq. in.), an elongation of 10% and a Rockwell G hardness of 54. Compacts normally were forged to 25% reduction, and in this condition had a density of 4.42, a tensile strength of 115,000 lb. per sq. in. (50 tons per sq. in.), 6% elongation, and a Rockwell hardness of G-81. Vacuum annealing for six hours at 1,000° C. gave a slight increase in density and reduced the strength and hardness to those of the sintered compact. These forged and annealed compacts were cold-rolled by slight reduction and many passes, with intermediate annealings after 15 to 20% reduction, and finished into sheet with 10 to 60% reduction.

Tensile strength was increased by cold-rolling up to 50% reduction and then dropped at 60% reduction indicating overwork (Fig. 1). Elongation decreased from 25% to 1.5% and the hardness increased steadily from G-76 to G-92. Rolling at 500° C. permitted greater reduction per pass and larger total reductions between annealings. The temperature was below the recrystallisation temperature of titanium and material so rolled work-hardened, but to a smaller extent than in cold rolling. Reductions of 80% raised the tensile strength and hardness and decreased the elongation (Fig. 2). Annealing after cold-rolling and hot-rolling produced similar properties for a given annealing temperature. Minimum strength was reached on annealing between 700° and 900° C. Cold-rolled and annealed material had a slightly higher tensile strength and hardness than cold-rolled material. Annealing temperature of 1,000° to 1,200° C. produced a small increase in tensile strength and a decrease in elongation.

The electrical resistivity of annealed wire of ductile titanium was 56×10^{-6} ohms per cc. and this value was not changed significantly by cold-working.

Iron-Manganese Alloys

By R. S. Dean, J. R. Long, T. R. Graham
and R. G. Feustel

AN investigation was carried out to determine the cold-worked and heat-treated properties of iron-manganese alloys containing 1 to 7% of manganese. The alloys whose compositions are given in Table 1 were prepared from Armco ingot iron and electrolytic manganese, melted in a high-frequency induction furnace and cast into chill moulds. Forging was carried out at 1040° to 871° C., followed by hot-rolling at 870° C., then a 35 to 40% reduction by cold-rolling to 0.312 in., the starting point for the rolling procedure calculated to produce $\frac{1}{16}$ in. sheet finished with definite amounts of cold deformation. The cold-rolled material was annealed at 785° C. for 30 minutes, followed by reheating to 620° C. for 1 hour and air cooling before further processing. The alloys were finished into $\frac{1}{16}$ in. thick sheet by rolling and annealing calculated to finish up with 20, 40, 60 and 80% reduction by cold rolling. The annealed or zero cold-worked state

was obtained by annealing material that had been finished by 60% cold reduction, using the treatments just described.

Heat-treatment experiments were carried out on test specimens cold-worked to 60% reduction and heated for 8 hours in a protective atmosphere of helium at temperatures ranging from 425° to 925° C. One set of these was cooled in the furnace and two sets were air-cooled. One of the air-cooled sets was then given a tempering treatment of 1 hour at 625° C. and again air cooled. This temperature was selected because most of the alloys showed minimum hardness and tensile strength with maximum elongation between 595° and 650° C. These treatments showed considerable variation in the properties with variations in annealing temperatures.

The results obtained showed that iron-manganese alloys, containing up to 7% manganese, were amenable to cold working and could be cold-rolled up to 80% reduction and the properties resulting from this cold deformation

determined on $\frac{1}{16}$ in. sheet. The 1 and 2% alloys could be readily rolled with relatively heavy reductions, while the 6 to 7% alloys, because of their greater strength and hardness, were reduced by much lighter reductions per pass.

The properties in the normalised and tempered condition showed a regular increase in tensile strength of about 5 tons per sq. in. for each 1% of manganese with an initial decrease of 5% in elongation, tapering down to about 1% for each per cent. of manganese at the higher manganese contents, while the hardness varied from Rockwell B-55 to C-23. The 7% manganese alloy had a tensile strength of 50 tons per sq. in., a yield strength

TABLE 1—COMPOSITION OF MATERIALS INVESTIGATED.

No.	C	Mn	Si	S	P
Armco	0.016	0.029	0.005	0.02	0.002
1	0.02	1.15	0.01	0.03	0.018
2	0.02	1.88	0.01	0.03	0.020
3	0.02	3.15	0.01	0.03	0.004
4	0.02	4.12	0.01	0.03	0.007
5	0.02	5.10	0.01	0.03	0.005
6	0.01	5.85	0.01	0.03	0.003
7	0.01	6.55	0.01	0.03	0.007
8	0.01	6.95	0.01	0.03	0.003

of 31.0 tons per sq. in., an elongation of 16% on 2 in. and a hardness of Rockwell C-23. In the cold-worked condition, the tensile strength was doubled by 80% reduction of the low-manganese alloys and increased by about 80% in the high-manganese alloys. The 7% alloy showed a tensile strength of 86 tons per sq. in. in this condition. The elongation was greatly affected by the initial reductions but decreased more slowly with additional working and was changed but little over the range 40 to 80% reduction. Manganese increased the elongation of heavily cold-worked material by a few per cent. for initial manganese additions after which the elongation remained constant.

Annealing and normalising treatments at temperatures up to 595° or 650° C. produced the usual softening of cold-worked material with greatest effects in this temperature range. In alloys from 3 to 7% manganese higher temperatures produced a hardening effect, due to the formation of a martensitic constituent resulting from the decomposition of the iron-manganese gamma solid solution. The properties of the alloys so treated varied with the manganese content and the heat-treating temperature. A tempering treatment of 620° C. superimposed on previously normalised material tended to produce substantially constant properties independent

From *American Society for Metals*, 1945, Preprint No. 8, pp. 1-22.

of the normalising temperature and approximating to those obtained by normalising from 595° C. A 620° C. tempering temperature appeared to be capable of producing the softest

condition in all of the alloys by modification of the martensitic constituent formed by the other treatments and by the production of a maximum amount of ferrite.

Solubility of Hydrogen in Molten Iron-Silicon Alloys

By H. Liang, M. B. Bever and C. F. Floe

THE results of an investigation of the solubility of hydrogen in representative compositions of the iron-silicon system up to 65% silicon at temperatures ranging from above the liquidus to 1,650° C. and at one atmosphere are presented. In choosing between the two methods for the determination of gas solubility in liquid metals, the extraction method was rejected because of anticipated difficulties in quenching and analysing the samples, and the hot volume method in which the solubility is determined by finding the difference between the volume of soluble gas admitted to the furnace at a certain temperature and pressure and the so-called hot volume, which is the volume of an insoluble gas necessary to fill the furnace under the same conditions, was used.

The apparatus used for the solubility determinations consisted of the furnace proper, a gas-measuring system, and gas-purification equipment. The chief parts of the furnace, Fig. 1, were a silica tube and a brass head in three sections, jointed together permanently by a piecein seal. For charging and cleaning, the top and centre sections could be removed in one piece, and these sections could be separated in order to insert a glass shutter which was used to protect the glass window in the top section from fogging during the high silicon runs. In the preliminary experimental runs, the metal was melted in alundum thimbles which were latterly replaced by beryllia crucibles backed by beryllia sand. To decrease the hot volume, the open space inside the furnace was reduced by a cylindrical sleeve of silica surrounded by silica rods. Argon, containing 0.5% impurities chiefly nitrogen, was passed through a furnace containing metallic calcium at 500° C. and then through a phosphorus pentoxide absorption tube, and hydrogen was purified in a furnace packed with platinised asbestos heated to 600° C. followed by an absorption tower

containing silica gel and a tube containing phosphorus pentoxide. The purified gases were admitted by a two-way stopcock to the measuring burette, which had a capacity of 100 cc. and could be read to 0.1 cc.

In making a run, weighted amounts of charge constituents were placed in the crucible, the furnace closed, sealed to the system, evacuated for an hour

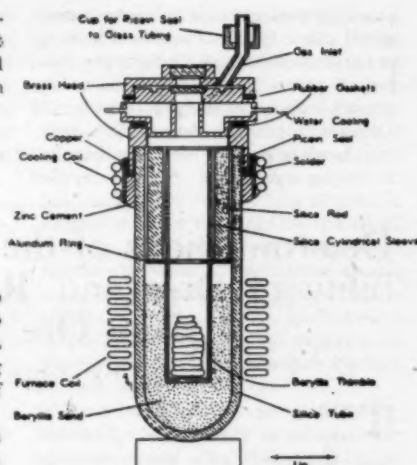


Fig. 1.—Furnace for solubility determination

TABLE I.—THE SOLUBILITY OF HYDROGEN IN IRON-SILICON ALLOYS AT ONE ATMOSPHERE.

Run No.	Composition		Temperature °C.				
	Wt. % Si	At. % Si	1,350	1,400	1,500	1,550	1,650
16 ...	0.08	0.25	—	—	—	29.2	33.5
22 ...	1.78	3.48	—	—	25.5	27.5	31.6
20 ...	11.0	19.7	11.5	12.5	14.4	15.4	17.4
18 ...	21.7	35.6	7.0	7.6	8.9	9.5	10.7
17 ...	31.5	47.8	—	6.0	6.5	6.8	7.3
25 ...	39.1	56.1	—	—	8.5	9.1	10.3
24 ...	45.7	62.7	9.3	9.9	11.1	11.8	13.1
21 ...	51.5	67.8	12.7	13.1	14.0	14.4	15.3
27 ...	63.7	77.7	29.7	21.4	22.4	22.9	23.8

or more and the molten charge held under vacuum for half an hour to extract any gases present. Hydrogen was then passed for one hour to deoxidise the metal, and the hot volume determined with argon. Burette readings were taken simultaneously with temperature readings until both the temperature and volume became constant. The hot volume in the various runs amounted to 70–90 cc. and its temperature coefficient averaged minus 2.5 cc. per 100° C. After determination of the hot volumes at four or five different temperatures, the argon was evacuated and hydrogen was measured into the system until the metal became saturated.

Two kinds of iron were used in the experiments, electrolytic iron of 99.9% purity and iron made from electrolytic sheet under hydrogen and containing 0.08% silicon. The metallic silicon had a purity of over 98% with iron the chief impurity. A silicon-bearing alloy made by melting electrolytic iron under hydrogen and adding silicon was also used. With the induction equipment available, alloys containing more than 70% silicon could not be melted. The solubility of hydrogen in iron-silicon alloys at one atmosphere and various temperatures is given in

Table I.

The results obtained from the various tests showed that the solubility of hydrogen in pure iron between the melting point and about 1,750° C. was nearly directly proportional to the temperature, and was a regular function of the composition. It decreased rapidly from the value for pure iron with additions of silicon up to 33% by weight or 50 atomic per cent., and increased again with a further increase in silicon. The minimum of hydrogen solubility at about 50 atomic per cent. was interpreted as an indication that undissociated iron silicide FeSi exists in the liquid phase and that the undissociated compound had a smaller ability for the solution of hydrogen than either of the constituent elements.

Platinum Ware

A new material, an alloy of all platinum family metals, has recently been developed in the United States. It is flexible and its outer surface reveals no scoring after numerous fusions. The ease of handling this new platinum material, trade marked CAPALOX PLATINUM resists the strain of experienced

From *Metal Technology*, 1946, Vol. 13, No. 2, and A.I.M.M.E. Technical Publication 1973, pp 1-9.

From *Chemical Industries*, October, 1945.

handling that eventually causes cracks in all other types. Capaloy Platinum is non-oxidisable, at all temperatures, for all practical purposes, due to the perfect balance of the platinum family alloys with pure platinum. It is resistant to all acids, but it may be attacked in boiling aqua regia. Being composed

of all platinum family metals, this alloy must be used with the same precautions as any platinum ware, namely, not to ignite phosphates or arsenates, nor reduce easily fused metals, such as lead, etc., in contact with it. It is available in the form of crucibles, dishes, wire, sheet, and foil.

Determinations of the Magnetic Susceptibility of Ores and Rocks from Swedish Iron Ore Deposits

By Sture Werner

THIS is an abridgment of a full report of the author's investigations published in the Yearbook of the Swedish Geological Survey, 1945, Ser C, N:o 472. The investigations clearly indicate that in the case of cylinder-shaped magnetite samples a demagnetisation factor

$$N = 2\pi \left[1 - \frac{p}{\sqrt{1 + p^2}} \right] \quad 1$$

should be used when calculating the susceptibility values, in any case as long as the susceptibility not essentially exceed 1. p denotes the relation between length and diameter of the cylinders. The formula corresponds to a homogeneous magnetisation of the samples.

The results regarding the susceptibility of ores and rocks within Swedish iron ore fields may be summed up in the following way:

For magnetite ores

$$x = \frac{Kv}{1 + CKv} \quad 4$$

For hematite ores (possibly also hausmannite and braunite ores), skarn, basic and acid rocks, limestone and dolomite

$$x = \frac{Kv}{1 + CKv} + 120 \times 10^{-6} (S_1 - S_0) \quad 9$$

S_1 indicates the spec. gravity of that part of the rock, which does not consist of magnetite, S_0 the spec. gravity of that part, which consists of quartz, feldspar, limestone and dolomite, K the susceptibility, v the volume fraction of the magnetite that is present in the ores and rocks, and C is called *internal demagnetization factor*.

For this factor the determinations of x and v in the case of ores with 30–100 vol.-% magnetite have given

$$C = \frac{4}{3} \pi \frac{1 - v^{1/6}}{v} \quad 6$$

From *Jernk. Annot.*, 1946, **130**, pp. 253–272.

When C is to be calculated also for lower magnetite contents this formula should be replaced by

$$C = \frac{4}{3} \pi \frac{1 - v^{1/6}}{v} \quad 7$$

In the groups skarn-bearing and calcareous iron ores and quartzeous iron ores the susceptibility¹ of the magnetite shows relatively small variations with an average value for K of 1.5 for the first-mentioned and 0.9

¹ The following data are valid for a magnetising field of the strength of the earth field.

for the last-mentioned group. In apatitic iron ores and manganiferous iron ores on the other hand, the variations in the K -values are very considerable (0.56 to 1.57 and 0.67 to 1.74 resp.), so the averages for K (1.03 and 1.20 resp.) obtained for these two iron ore groups as a rule do not by far represent the individual iron ore deposits. The susceptibility of a skarn-bearing and calcareous iron ore or a quartzeous iron ore may thus broadly speaking be considered known if only the magnetite content is known. For an apatitic iron ore or a manganiferous iron ore on the contrary it is as a rule necessary also to determine the susceptibility of the magnetite contained in order to allow of a reliable estimation of the susceptibility of the ore.

The influence that the paramagnetic constituents of a rock have on its susceptibility is perceptible only when the magnetite content in the rock does not exceed some few volume %, so the second term in formula 9 may otherwise be disregarded. The lower the magnetite content of a rock, the more independent is its susceptibility of the variations in the K -values of the magnetite.

Photocolorimetric Method of Determining Silicon in Hadfield Steel

By A. I. Kokorin and K. D. Vasileva

ALTHOUGH manganese steel is easily attacked by HNO_3 (1:1) and the silicon goes completely into solution the colorimetric determination of silicon by the molybdate-stannous chloride method fails because of the presence of HNO_3 . The following method, in which solution is effected by means of dilute H_2SO_4 and perhydrol is recommended.

0.25 g. of steel in a small conical flask is treated with 4–5 drops of perhydrol and then with 36 ml. of hot H_2SO_4 (1:8). When the reaction dies down the solution is boiled for 1–2 min., 5 ml. of 4% KMnO_4 solution are added, and the solution boiled again for 2–3 min. The precipitated hydrated MnO_2 is dissolved by the addition of a few drops of perhydrol to the cooled solution, and the excess is removed by boiling for 1–2 min. The clear solution, after cooling, is transferred to a measuring flask and made up to 250 ml. with water. 5 ml. of this solution are then pipetted out

into a 50 ml. measuring flask, treated with 5 ml. of 5% ammonium molybdate solution, and allowed to stand for 3–4 min. for the development of the yellow molybdenum complexes of Si, P and As, after which 25 ml. of H_2SO_4 (1:8) are added to prevent interference by P, As, and excess molybdate in the subsequent reduction and the solution is well mixed. Reduction is carried out by the addition of 5 ml. of 0.5% stannous chloride solution. Water is added to the mark, the solution is well mixed, and then placed in one of the cells of a compensation photocolorimeter, where it is compared with a blank.

The calibration curve is constructed by using standard Hadfield steels of known Si content, or from standards prepared as follows: various quantities of a standard silicate solution, containing 0.5 mg. of Si and above, are run from a burette into 100 ml. conical flasks, each containing 10 ml. of an iron solution equivalent to 0.025 g. of Fe; 4–5 drops of perhydrol,

From *Sarad. Lab.*, 1946, **12**, 125.

and 36 ml. of H_2SO_4 (1 : 8) are added, the solutions are warmed, treated with 4% $KMnO_4$, followed, after slight cooling, by a few drops of perhydrol to reduce $KMnO_4$, and then made up to 250 ml. in measuring flasks. Each is then treated as given above, for the analysis of steels.

New Heat-Treatment Neutralising Chemical

By W. M. Sutherland

THE heavy demand for chromium compounds and other critical products used in neutralisation of heat-treating baths for aluminium alloys has served as the spur in the search for substitute chemicals. It was found that sodium acid sulphate not only gives successful results, but saves approximately 75% in cost of materials. Molten sodium nitrate is commonly used by the aircraft industry as "liquid heat" in the heat-treatment of aluminium alloys. The sodium nitrate bath is operated at temperatures as high as 510° C. Since sodium nitrate starts to decompose at 380° C. there is considerable breakdown of the salt at 510° C.

One of the end products from the sodium nitrate decomposition is sodium oxide which in contact with water produces sodium hydroxide, a strongly alkaline compound. Aluminium alloys are susceptible to corrosive attack in alkaline media. Some aluminium alloy parts, such as rivets, are heat-treated after an anodic treatment, which forms a coherent absorptive film of aluminium oxide on the surface of the part to give protection from corrosion and furnishes better paint bonding. This coating also is attacked by alkalis. The amount of alkali produced in a day by the decomposition of the sodium nitrate may amount to as much as 0.005%. In order to neutralise this alkali, sodium dichromate, an inherently good corrosion inhibitor, is added to the bath.

Sodium acid sulphate proved to be a satisfactory substitute for sodium dichromate in sodium nitrate baths. Commercial sodium acid sulphate assaying 80% and containing less than 2% moisture can be obtained readily and cheaply. This compound neutralises the alkali produced in the bath by a straight acid-base reaction. Neutral sodium sulphate is gradually built up in the bath as a by-product. Water

The blank is obtained similarly but without silicon. 25 mm. cells and yellow colour filters are used. The zero is obtained on blank solutions and an optically identical cell containing the test solution is substituted for one of these cells and the scale deflection read.

formed during the reaction goes into the gaseous phase at the temperature of the reaction. Additional sodium nitrate is added from time to time to make up for the salt lost when parts are removed from the bath. The concentration of the by-product reaches an equilibrium at a point dependent upon the ratio of sodium sulphate to the sodium nitrate added per unit time.

Splattering was encountered at first upon the addition of the sodium acid sulphate to the bath. The water content of the salt is a controlling factor of splattering, and a content of less than 2% has been found to be safe. Daily laboratory control of the alkalinity of the heat-treating baths is

maintained by titrating a water solution of a weighed sample of the cooled salt with 0.1% sulphuric acid, using phenolphthalein as indicator. Each 0.1 cm.³ of acid required to neutralise the salt indicates that 1 lb. (450 gm.) of sodium acid sulphate should be added to an average size rivet pot [containing 700 lb. (320 kg.) of sodium nitrate] in order to neutralise the alkali present. The amount of sodium acid sulphate necessary to neutralise a bath is not stoichiometrically related to the alkali present, since considerable amounts decompose and vaporise at the surface of the bath before contact is made with the alkali.

Titration curves, prepared to study the buffer characteristics of a water solution of the salt, indicate that the addition of sodium sulphate narrows the pH range where buffer action takes place, but that the pH value where equinormal quantities of both sulphuric acid and sodium hydroxide are present during the titration is the same, pH 9. Phenolphthalein which has a range of pH to 10 is a satisfactory indicator for this titration. Results of accelerated corrosion tests on aluminium alloys heat-treated in a sodium nitrate bath containing 10% sodium acid sulphate differed little from tests made on samples heat-treated in sodium nitrate baths containing sodium chromate.

Carbide Analysis

AS is well known, electrolytic solution of steel under special conditions leaves the carbides in a state which can be examined by chemical and X-ray methods, but the actual methods of analysis to be employed have been the subject of critical study for many years past since the separation of the individual constituents is a matter of some difficulty. Finality has not yet been reached but already a number of valuable results have been obtained.

Professor Kishkin, of the Institute of Aviation Materials, on the basis of carbide analysis (Popov's method), has been able to show that iron carbide in a highly-dispersed form is produced during the process of plastic deformation of quenched steel. The carbide blocks the slip-planes and thus explains work-hardening and the great degree of hardness associated with martensite. With small amounts of plastic deformation martensite is not hard but soft. It is stated that the chemical method is the only one which

has been successful in demonstrating that cold-work produces highly-dispersed iron carbide, other methods, including X-ray, were ineffective.

Since the quantity of carbide formed increases with the deformation it is possible to study the degree of plastic deformation inside the material as well as on the surface by means of carbide analysis. This gives a new means of investigating stress and strain relationships.

A connection has now been found between the strengthening produced by cold deformation and that produced by tempering. By means of X-ray studies of carbide precipitates (Kishkin and Kosolapov) it has been shown that tempering at low temperatures gives iron carbide in the form of plates, about 10^{-6} cm. long and about 10^{-7} cm. thick, but that at high temperatures the lamellar structure disappears (on account of the great speed of coagulation). Thus the basic factor in the strengthening of steel, whether by cold deformation or by thermal treatment, is the process of

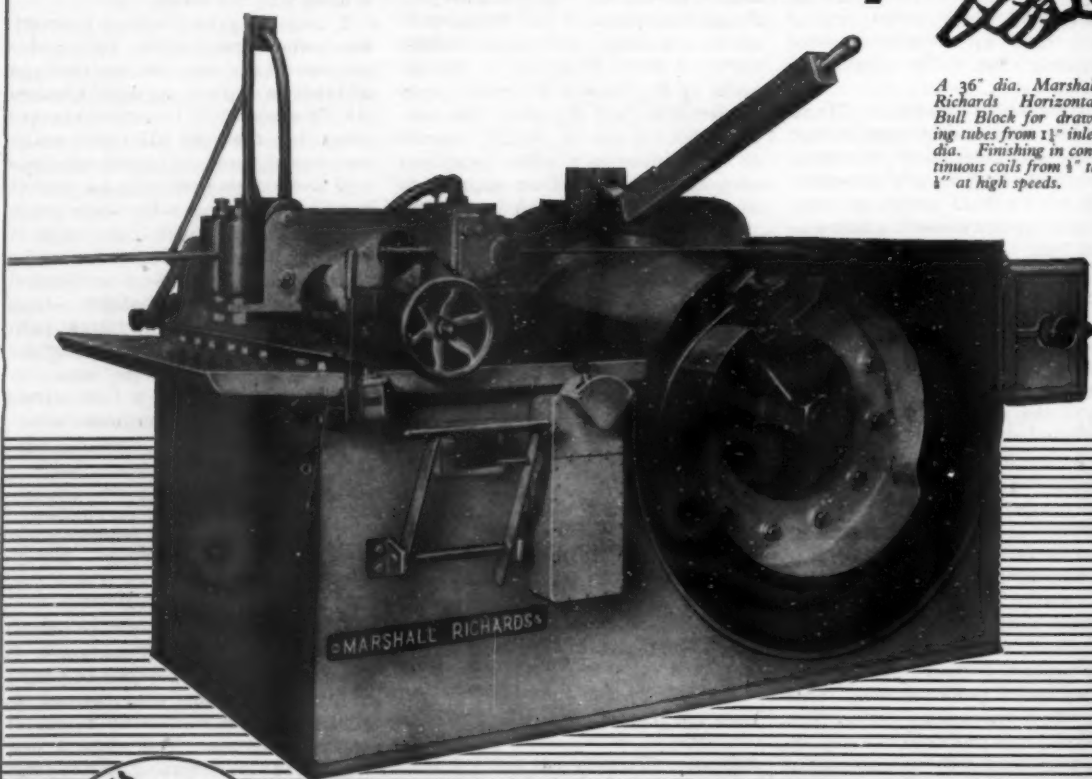
From *The Iron Age*, October 4, 1945.

From *Zavod. Lab.*, 1946, 12, 1.

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carbide formation, and the problem of the great degree of hardness of martensite must be considered as part of the problem of hardening through cold work.

Carbide analysis is being used (Kishkin and Bokshtein) to show how the alloying of steel affects the rate of decomposition of martensite during low and high temperature treatment. Silicon is found to exert a hindering effect, particularly at low temperatures. Kinetic curves, based on carbide analysis, of martensite decomposition, in the case of low-alloyed

steels, have given valuable data for building a new theory of alloying.

New data have also been obtained on the kinetics of isothermal transformation of low-alloyed steels. Just as the magnetic method gives a fairly clear picture of the decomposition of austenite in isothermal transformation, so carbide analysis indicates under what temperature conditions, and with what speed, carbide formation occurs. In the case of all pre-eutectoid steels, it begins after the decomposition of austenite.

Rapid Test for Fluidity Measurement

By G. B. Taylor

THE necessity of obtaining an approximate measurement of the fluidity of cast iron in order to determine its suitability for a given section is obvious to any practical foundryman. It is not unusual to find that although the metal was melted hot, wedge control appeared satisfactory and the metal appeared to be hot enough in the ladle, the metal poured into the mould was not in a condition suitable for running thin sections and waster castings have resulted.

No one would wish to deny that metal temperature, composition, and wedge control are functions affecting fluidity, but the fact remains that these are not the complete answers and the desirability of instituting a quick and practical test which may be carried out on the job immediately prior to casting is clearly indicated. The standard spiral fluidity test has been in use for a number of years, but has never given entire satisfaction. Results have been inconsistent, and there is, of course, a time lag between casting the test piece and determining the length of the spiral. This time lag is a factor which must be reckoned with when a considerable number of hand shanks are being fed from the same ladle, since it is possible that between the time of casting the test pieces and determining the length of the spiral, many shanks may have been filled with metal and the iron poured into moulds.

A modification of the standard spiral fluidity test eliminates this undesirable time lag. The outer ring of the spiral mould is arranged to carry small openings at regular intervals through which metal can pass out of the mould if it is fluid enough. It is shown that the test piece is formed by two oil

sand cores. The lower half containing the modified form of spiral and the upper half the runner basin and strainer cores. Note that the metal is not poured directly on top of the strainer core but into a well at the side, thus allowing greater ease for the pouring basin to be kept full. The strainer core is set well below the top of the outlet

from the pouring basin to allow for a reasonably constant ferrosstatic head above the strainer. The two halves of the core are held together by weights or by means of a simple clamp.

As indicated, the metal passes from the well beneath the strainer core to runner bar concentric with the outside wall of the core and at regular intervals branches are made to radiate from the ring to the outside of the core. These branches provide the means of determining, without stripping the core, how far the metal has run in the concentric ring, since it will obviously flow out of each hole in turn as it travels round the ring.

It only remains to decide out of how many holes the metal must flow in order to be suitable for a given metal section, that is, it may be that to run a section $\frac{1}{8}$ in. thick requires that metal flow out of four holes. With this knowledge tests are taken frequently during casting and, immediately the number of holes through which the metal flows falls below four, casting is stopped and the metal returned or put into thicker section work.

Corrosion Fatigue

Properties of Hard Lead Alloys in Sulphuric Acid

By D. J. Mack

AN investigation was undertaken to determine: (a) the reduction in fatigue strength of pure lead and several of its common alloys when corrosion in battery acid was combined with fatigue; (b) the straight corrosion rate of these alloys in battery acid; (c) the correlation, if any, between (a) and (b). The observations made during the investigation led to an examination of the mechanism of corrosion fatigue action of sulphuric acid on lead and lead-rich alloys. Notch sensitivity of pure lead was also studied.

The corrosion-fatigue properties were determined of pure lead, tellurium lead, 1% antimonial lead and commercial storage battery lead. The compositions of the alloys used for the tests are given in Table I. These alloys were cast into graphite moulds at 175° C., aged for 48 hours at 160°, and forged after ageing to $\frac{1}{2}$ in. diameter test specimens, with the exception of the last alloy which was machined directly after ageing. Ageing was carried out in order to eliminate

irregular test results. Tests were carried out on a rotating beam fatigue testing machine of the cantilever type operating at a speed of 1,785 r.p.m. The endurance limits of the four types of lead were determined: (a) in air, the test specimens being coated with vaseline; (b) in 38% sulphuric acid; and (c) in air after the specimens had been previously corroded in sulphuric acid while stress free.

The endurance limits of the four alloys as determined from their S-N curves, after testing in air, in 38% sulphuric acid, after stressless corrosion tests in 38% sulphuric acid, and fatigue tests in air after stressless corrosion in 38% sulphuric acid are given in Table II. Stressless corrosion tests were carried out by suspending on glass hooks broken fatigue specimens in 38% sulphuric acid for one week at 20° C. Notched-bar fatigue tests carried out on the pure lead at 1,785 r.p.m. showed an endurance limit of 170 lb. per sq. in., when the test specimen had a reduced section formed by a 60 deg. V notch, as compared with the polished reduced

From *The Iron Age*, April 11, 1946.

From Amer. Soc. for Testing Materials, 1945, Preprint 32, pp. 1-23.

TABLE I.—COMPOSITION OF ALLOYS USED IN CORROSION-FATIGUE INVESTIGATION.

Alloy	Sb	As	Sn	Fe	Cu	Te	Ag	Bi	Pb
Electrolytic Lead (Pb) ...	0.004	Nil	—	0.0015	0.008	—	0.0003	0.0016	Bal.
Tellurium Lead (Te) ...	0.007	—	—	—	0.063	0.050	0.007	—	"
Antimonial Lead (1 Sb) ...	1.005	—	—	—	—	—	—	—	"
Storage Battery Lead (8Sb) ...	9.36	0.047	0.434	0.0006	0.020	—	—	—	"

TABLE II.—ENDURANCE LIMITS AND STRESSLESS CORROSION TEST ON LEAD ALLOYS.

Alloy	Endurance Limit in Air at 1,785 r.p.m. lbs. per sq. in.	Endurance Limit in 38% Sulphuric Acid at 1,785 r.p.m. lbs. per sq. in.	Endurance Limit in Air at 1,785 r.p.m. after Stressless Corrosion in 38% Sulphuric Acid lbs. per sq. in.	Stressless Corrosion in 38% Sulphuric Acid *
Pure Lead ...	430	0	475	+0.16
Tellurium Lead ...	600	400	1,300	+0.78
1% Antimonial Lead ...	860	740	4,200	+0.52
Storage Battery Lead ...	2,050	1,850	2,050	-1.41

* Corrosion rate expressed as change in weight per grm. ($\times 10^4$).

section with a 2-in. radius as used on all the other tests.

The results obtained showed that it was necessary to over-age lead and its alloys in order to get reproducible results in fatigue testing, and that lack of consistent ageing was probably the cause of much of the discrepancy in previously reported fatigue results on lead and its alloys. Over-ageing, however, did not reproduce commercial battery grid practice. The results obtained for pure lead were fairly consistent with the values for fatigue by other investigators, but the results obtained for 1% antimonial lead and tellurium lead did not agree with previously reported values, due possibly to ageing effects or the effect of creep and consequent variation of endurance limit with frequency of cycles of stress.

The corrosion fatigue strengths of the four alloys were determined by a running balance between corrosion resistance and fatigue strength. There was no correlation between fatigue strength in air, corrosion-fatigue strength in 38% sulphuric acid and stressless corrosion as determined by loss of weight in 38% sulphuric acid. There was a good correlation, however,

between fatigue strength in air and fatigue strength following stressless corrosion in 38% sulphuric acid which indicated that corrosion and cyclic stress occurring simultaneously cause serious damage. Since the effect of corrosion-fatigue was variable in the four alloys, it was assumed that it affected other lead alloys in similar variable fashion. Corrosion-fatigue was probably, therefore, one of the variables that prevented correlation of laboratory and service tests on battery cells when the performance characteristics of new grid alloys were being investigated. In at least one case, the 1% tin, 0.1% magnesium alloy, a lack of adequate corrosion-fatigue strength was probably the chief cause of lack of correlation between laboratory and service tests in batteries with this alloy in the grids.

The pure lead tested was found to be very susceptible to the notch effect and this was considered to be the chief factor in propagation of the fatigue crack, although breathing action due to stress reversal might also aid in propagating the crack.

As a result of the various tests a mechanism for corrosion-fatigue action of sulphuric acid on lead is proposed.

It is suggested that the lead sulphate film which normally protects lead against sulphuric acid is damaged in two ways by cyclic stress: (a) the adherence is affected by the tendency of the lead to recrystallise during stressing; and (b) the cyclic stresses open up cracks in the protective film.

Determination of the Depth of Surface Decarburisation in Rolled and Drawn Steel

By Hans Kjerrman

AS a preliminary to standardisation the author has made a survey of different methods in use for determining the surface decarburisation of steel. In practice the most appropriate method is to measure the thickness of the decarburised surface layer microscopically on an etched cross section.

It may, however, admit of some question to which depth the decarburisation should be measured, and the author gives three alternative definitions:—

a = surface decarburisation layer, in which the structure consists of ferrite, i.e., where the carbon content is practically nil.

b = surface decarburisation layer, in which the structure may vary from 100% ferrite to 100% lamellar pearlite, i.e., up to eutectoid composition.

c = surface decarburisation layer, in which the structure indicates a lower carbon content than the average of the steel.

Examples of measurements according to these three definitions are shown in micrographs.

From *Jernsk. Annal.*, 1946, 190 pp. 239-252.



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